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PROMINENT MEMBERS OF THE FRANKLIN INSTITUTE

5. ALEXANDER DALLAS BACHE, 1806–1867

BY

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If ever a man was saddled with the responsibility of having to live up to family prestige, it was Alexander Dallas Bache. He was the son of Richard Bache, one of the eight children of Sarah, the only daughter of Benjamin Franklin. His mother was Sophia Burret Dallas, daughter of Alexander J. Dallas, who was Secretary of the Treasury under President Madison, and sister of George M. Dallas, Vice President to President Polk. Although this relationship might be regarded as a handicap for a man to gain individual distinction, it was successfully overcome in this case.

Dallas, as his friends chose to call him, was born on July 19, 1806, at 74 Walnut Street, Philadelphia. He was a shy sober youth, without that humor and urbanity which developed at maturity. There is some doubt about the school he attended, but it was probably Clermont, a classical academy situated near Frankford. He completed his education here at the age of fifteen and went directly to West Point, where he was the youngest cadet on the rolls. The class started with sixty-five cadets and finished with only thirty-six. During his four years of training Dallas maintained his place at the head of his class. It was related of him during these years he was impressed beyond his years with a sense of the responsibility that would devolve upon him as the senior member of a large family. The necessity for cultivating this sense of responsibility was real. His father, one-time postmaster of Philadelphia, was a rover who had gone off to Texas, and it is improbable the boy ever saw him again. Dallas was also conscious that his descent from Benjamin Franklin imposed upon him more than an ordinary responsibility.

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As this feeling of what amounted to dedication grew upon him, it produced a change in his character. For, when a child he is said to have been quick tempered, a characteristic that was replaced by gentleness and an evenness of temper that endeared him to friends, although he was capable of sudden gusts of anger that were the more conspicuous and effective because of their rarity. Another trait of character developed in these early years was a firm determination that whatever he had to do would be well done. As an example of his youthful persistence in accomplishing a task, a story tells that, when he had to prepare a recitation of unusual length or difficulty, he would prop himself upon a stool of uncertain equilibrium which collapsed whenever his thoughts wandered from the task in hand.

After graduation, Dallas remained at West Point as assistant professor of engineering. He remained at this post for one year before being transferred at his own request to regular army life. He was assigned to engineering duty at Newport, R. I., for work on the construction of Fort Adam. Here he read voraciously, especially on physics and chemistry. It is interesting that during his leisure he made a scientific study of the shells found in the neighborhood. The social amenities of the place were not overlooked and Dallas had the opportunity to meet Nancy Clarke Fowler, who inspired him with thoughts of matrimony. The support of a wife, his mother, and her brood of children upon a lieutenant's pay caused this anticipated pleasure to be postponed indefinitely. After two years of army duty, the chair of natural philosophy and chemistry at the University of Pennsylvania was offered him. This unexpected windfall made marriage possible.

Dallas Bache entered upon his new duties as professor in October, 1828, when he was twenty-two years old, younger than many senior college students of today. The change in location was acceptable. He was back among the friends of his childhood, and he rapidly enlarged the circle of acquaintances. Within six months of his arrival in Philadelphia he was elected a member of the American Philosophical Society and of The Franklin Institute, one founded by his great-grandfather and the other bearing his name. Both these societies provided him with the stimulation for scientific research and sharpened his debating powers.

Association with the Institute proved to be invaluable, since it brought him into contact with the principal manufacturers, engineers, and artisans, and it enabled him to establish friendly relations with the younger generation of men who were to extend their influence over public affairs. The practical knowledge he acquired from this association was useful to him as a teacher. At the University he was able to provide demonstrations of a few scientific principles, but there was no laboratory work for the students. Most of the instruction was bookwork supplementing the professor's lectures. With the practical knowledge he secured through his Institute connections, Bache was

enabled to make his lectures much more interesting to his students by associating his teaching with the practical applications of the principles under study.

It should be remembered this was a notoriously stormy period in college history, when the insubordination of the students was a cause for grave complaint. However, it is related of Bache that his students had so high a regard for him, there were no reports of disorder in his classroom.

Another advantage he enjoyed through his membership in the Institute was that workshops were thrown open to him where skilled hands were to be found that could execute his ideas.

His energy in those University days was prodigious. Although he had to meet three classes a day, Sundays excepted, he still found time for private research, attendance at meetings of the learned societies he had joined, and to attend to social duties. He was placed upon several committees because of his willingness to work. Such activity could not have been maintained over any great length of time without a well organized day, in which each occupation was allotted a certain time. He drew up a schedule of hours, and he tried to keep within it.

A generous amount of time outside the hours of teaching was devoted to committee work for The Franklin Institute. The reports of stated meetings held between the years 1828 and 1835 bear testimony to the regularity of his attendance and of the lively interest he took in the proceedings. But it was in committee work that his influence was mainly felt. He served on several of the committees, notably those on meteorology, inventions, meetings, and publications, and he was conspicuous in the work of the special committees appointed to investigate water power, steam-boiler explosions, weights and measures, patent law, etc.

His dynamic personality had a great deal to do with the success of the committees that investigated water power and steam boilers. He devised many of the experiments that were performed. In the case of the boiler-explosions investigation he frequently conducted the tests that called for physical courage of a high order for, in the absence of acquired experience, danger was present at every stage. There were so many resounding explosions of boilers under test, that the residents of the immediate neighborhood were moved to protest against the disturbance of their peace.

The reports of this committee were highly appreciated, for they incorporated proposals and recommendations that were to influence boiler construction and maintenance for the next forty years.

Bache's interest in the Institute's activities was recognized in 1831 by his election to the Board of Managers, in which office he remained until 1839, when he was made Corresponding Secretary. He retained this office until 1843, when he left Philadelphia for Washington.

During the years when he was so active in the work of the Institute

and in the American Philosophical Society, he was engaged in conducting his own independent research. He had constructed an observatory in the garden of his home on "Chestnut Street near Schulkill Sixth," now 17th Street. Working here with the assistance of his wife and John F. Fraser, a former student, he determined with accuracy for the first time in this country, the periods of the daily variations of the magnetic needle and, by another series of observations, the connection of the variations of the direction of magnetic force with the appearance of the aurora borealis.

This marked the effective beginning of a lifelong interest in geomagnetism.

At his home he also made a series of investigations with Fourier's thermoscope of contact. Finding the results to be unsatisfactory, he developed a new thermoscope of contact better adapted to his purpose. The elaborate apparatus he had constructed for this work had involved him in the outlay of more money than he could conveniently afford when his mother, entering the room in the dark, accidentally overturned the whole glass construction. He did not attempt to reconstruct it, and the incident has been preserved to illustrate his remarkable control over his emotions rather than for the nature of the studies he had proposed to make. It is related that no word of reproach escaped his lips.

The study of meteorology occupied part of his time, not only on the Institute committee concerned with the organization of observers, the distribution of instruments, and the collection of records, but also in independent research. He formed an intimate friendship with James P. Espy, known as the "Storm King," with whom he made a minute study of the track of a tornado which visited New Brunswick, and established the fact that the effects of this type of storm were due to an ascending and progressive column of air.

But his principal interest was with terrestrial magnetism. To this field he always returned after his attention had been diverted by some phenomenon or task that claimed his time.

In 1836, the whole of his energies were directed into a fresh channel. Five years earlier, the famous financier and merchant Stephen Girard had died, providing in his will a generous fund for the establishment of a school for orphans. Bache was selected by the Board of Trustees (one of whom was Samuel Vaughan Merrick, founder of The Franklin Institute) to be president of the projected Girard College.

There was no precedent in this country for a school such as Girard had contemplated, and the trustees were determined to provide the students with the very best education available. Bache was instructed, therefore, to make an unhurried tour of Europe for the purpose of visiting schools, and to collect the information that would enable the trustees to build an organization and decide upon a curriculum designed to give the best expression to the founder's intentions.

Bache's tour took him through Britain, France, Germany, Austria, Italy, and Switzerland. He visited all the schools and colleges of any repute and made detailed inquiries into all phases of their work. His reputation as the great-grandson of Benjamin Franklin secured him an introduction to all the scholars of Europe who were interested in education, and he took the opportunity to secure their views on the subject. He was received everywhere with marked attention because, apart from his ancestry, his published researches had furnished him with a wide personal reputation among scientists.

He did not want for any variety in his experiences. He visited quarries, iron works, dye works, gas works, a carpet factory, a coal mine, docks and warehouses. Nor did he neglect social functions. Indeed, he so crowded his days with engagements that he began to suffer from fatigue and was delighted to have the company of his friend Joseph Henry of Princeton, with whom he "did" some of the sights and forgot the problems of education for the time being. The pair had an enjoyable experience scouring the stores of the different instrument makers in search of scientific apparatus for their colleges, which was unobtainable in their own country.

On his return to Philadelphia, Bache presented the trustees of the college with a voluminous report in which he furnished an exhaustive analysis of all he had seen and heard during his European tour. He stated more than facts derived from his observations of the various school systems he had seen, for he offered many inferences and deductions he had made. When the report was published it was accepted as the most comprehensive work on education available in America, and it had a marked influence upon the theory of education in this country.

However, the trustees were not yet in a position to implement the many ideas he advocated for adoption. They were having difficulty in getting a settlement of the funds Girard had bequeathed for the foundation of the College. The buildings were still incomplete. The president was condemned to inactivity at the time he was most desirous of applying the knowledge he had gained on his European visit.

It chanced that the Central High School had been in operation for a year without any principal. Seeing an opportunity to apply some of the new ideas he had developed from his recent experiences, Bache offered his services to the school and, in 1839, he was appointed to the vacant post of principal. As an example of his integrity, it should be noted that he renounced his salary as president of Girard College (although he retained the post) as soon as it became apparent the trustees were not prepared to open the school so that he could exercise the functions of his office. This voluntary sacrifice compelled him and his wife to adjust themselves to living upon the reduced salary received from the city for his work at the High School.

Bitter acrimony developed between the trustees of the College and

the city authorities over the disposal of the funds in Girard's bequest. Bache held himself aloof from the dispute and emerged from it with the respect of the disputants on both sides. His administration of the High School won for him the esteem of the city authorities, and the results he obtained justified them in asking him to assume responsibility for supervising all the public schools in the city. In this office he also met with conspicuous success.

There are many tributes paid to Bache as a schoolmaster and teacher but none were warmer than those paid him by his former students. He was the founder of the Bache Institute, an organization of alumni origin, and years later the Alumni Association of the Central High School honored his memory by creating the Alexander Dallas Bache Physics Prize.

During his visit to European countries he had diligently pursued his investigations into terrestrial magnetism, making frequent measurements relating to dip and intensity at the various places he visited. On his return to Philadelphia he persuaded the trustees of Girard College to build an observatory of his own design, with wooden walls, copper nails, brass hinges, foot-thick partitions, and double doors, and generally with a total absence of the iron or any condition that would interfere with observation and making precise measurements of the earth's magnetism. In this building a series of observations were made at frequent intervals, day and night, during the years 1840–45. When Bache could no longer supervise the work of the corps of observers the elaborate program was continued under Professor John F. Fraser, who shared his former tutor's enthusiasm for the subject. At a later date, Bache was to make a painstaking analysis of the vast accumulation of data which, with an interpretation of the results, was published in three volumes under the Topographical Bureau of the Federal Government. This remained the authoritative work on terrestrial magnetism for many years.

Meanwhile, Bache's career had undergone another change of direction. His successor at the University of Pennsylvania had resigned. The teaching there had failed to maintain the high standard Bache had set, and the Board of Trustees were desirous of restoring it. They invited Bache to return to his old chair, and he promptly accepted the invitation. Relieved of the cares of administration, he threw himself enthusiastically into teaching, an occupation for which he displayed a natural talent and one which afforded him full opportunity to cultivate his interest in people and their development. In a sense, it was unfortunate that this renewal of association with the University was to be of short duration, for he had great talent for working with young people and encouraging them to work toward a high intellectual standard.

At the suggestion of his many friends in the American Philosophical Society he was persuaded in 1843, to apply for the appointment as Superintendent of the United States Coast and Geodetic Survey. This

bureau had been established by Thomas Jefferson on the suggestion of the Swiss-born engineer Ferdinand Hassler, who was the first to fill the office of superintendent. For various reasons, but mostly because of policy changes dictated by the government, little more than a beginning had been made upon the important work the bureau was intended to perform. Bache's application for the post was approved.

Under his superintendence the work underwent a great change, and he was able to attain a remarkable degree of accomplishment. Because of this survey countless ships and the lives of their crews have been saved from the rocks, shoals, and reefs of the coast. The channels of the seaboard have been explored and recorded upon charts. Ocean currents have been charted, variations of the compass needle and its rate of change have been determined. Tidal laws were formulated and accurate tide tables have been published for the guidance of mariners.

When Bache took office only the surface of the work had been scratched. The survey had been restricted to the coast between Point Judith on Rhode Island and Cape Henlopen at the entrance of Delaware Bay. He devoted his first year to fixing his bearings in the new work and to making the influential friends necessary to liberate the survey from the domination of the politicans who had restrained its development. When this experience had furnished him with the required knowledge of the situation, he was in a position to embark upon a greatly extended program, although one can perceive caution in his haste to produce results. One of the significant features of his conception of the task confronting the survey was his approach to the work in a manner that would ensure broader government support. Instead of limiting the survey to the coast immediately north and south of New York, he instituted a number of widely separated stations. This geographic expansion had the practical advantage of gaining support from the representatives of more states in the constant struggle for adequate appropriations. The wider support thus obtained ensured the expansion of the work undertaken by the Survey.

Bache was not unmindful of the need to have the approval of his scientific colleagues and the public at large. He invited the co-operation of the American Association for the Advancement of Science to express an opinion upon the usefulness of the work, and the members responded with a strong endorsement of its national magnitude and character. He used both shoe leather and pen to secure a larger annual appropriation. In this regard he met with success, but while he was able to have the appropriation doubled, the amount of work he had taken in hand had trebled the activities. This failure to keep financial support in step with achievement at times caused him despondency, but he never ceased to fight for more money to continue the work on the broadest scale. Nor did he ever permit discouragement to lower the quality of his staff's work.

Not all of his time was devoted to desk work. He tried to spend as much time as possible in the field, but he found the annual report he had to prepare for Congress a severe hindrance to freedom of movement. Each report covered several hundred printed pages, with many maps and plates, so that he was confronted with a formidable task in compiling them at the end of each year. Although these reports demanded a great deal of painstaking preparation, he was able to make arrangements whereby he could complete the work on them while continuing his field work. The reports were dated from sites on his field trips ranging from Maine to North Carolina.

In the twenty-odd years Bache was superintendent of The Coast and Geodetic Survey he raised its status from insignificance to the first rank. This was largely due to his personal direction of his staff's work; to his wise selection of qualified assistants who were able to obtain the maximum results from the amount of effort applied; and to his introduction of the instruments especially designed for promoting the work. The apparatus he designed for measuring base lines furnished an accuracy that was almost unbelievable. An immense triangulation running from the farthest corner of the State of Maine to the southern tip of Florida, in which thousands of triangulations were made, was found to be only eighteen inches out when completed. Numerous other instruments were made that won the admiration of those best qualified to appreciate their merits.

The most satisfactory aspects of his association with The Coast and Geodetic Survey was the improved staff he assembled about him. There was an intimacy in the staff relations rarely to be found in operations that were carried out over a widely extended geographical area. He still had to exercise some of the functions of a teacher. When he engaged a new member of the staff, he kept in touch with the newcomer, either personally or through a lieutenant, checking the accuracy of his work, encouraging his enthusiasm, and giving him hope. As a result, the entire staff was devoted to him.

In addition he enlisted the services of the best scientific men in the country, either as regular members of the staff, as temporary assistants to undertake special tasks, or as friends who, for the love of the man and interest in his work, were always ready to contribute advice or co-operation.

During the entire time he was engaged with The Coast and Geodetic Survey, Bache kept in close touch with his scientific friends. One reason for this was because he wished to be kept informed of the unusual young men whom he could recruit into the service of the Survey, but more particularly because he had to keep abreast of progress in the scientific world. This was of primary importance because of the exceptionally wide field he had to cover, for his scientific range covered everything between life on the ocean floor and the stars in the heavens.

In 1833, Bache had been actively engaged at The Franklin Institute on a committee charged with the investigation into the standards of weights and measurements in the State of Pennsylvania and the supervision of the construction of the standard units. Ten years later he was appointed Superintendent of Weights and Measures of the United States. This work had been entrusted to Hassler in 1835, but little progress had been made in completing the work. Bache infused energy into the accomplishment of the task, completed the necessary standard units, and distributed them to the customs houses throughout the country. This department was the progenitor of the Bureau of Standards which found so many ardent advocates in The Franklin Institute, notably Professor Munro Snyder of the Central High School.

Although primarily a scientist, he did not confine himself to the study of pure science, but was deeply interested in technical developments, and was quick to take advantage of any that could be usefully employed in the work of the Survey. From his earliest days in office as superintendent he urged the use of steamboats to replace the sailing vessels the bureau owned and operated. He early saw the advantages of the electric telegraph as a means of rapid communication, and freely employed it in his official work. Among other technical advances he introduced were the use of photography for the reproduction of charts, and electro-typing for the multiplying of copper-plate engravings.

When the government received the Smithson bequest for the foundation of an institution for the promotion and diffusion of knowledge, there followed a wild scramble by legislators and the public for a share of the funds to carry out local or restricted institutions. Bache, as a recognized leader in scientific thought, was named to the Board of Regents of the Smithsonian Institution. He was largely instrumental in persuading his friend Joseph Henry to accept the secretaryship of the Institution, and the two men led the battle to secure a firm observance of Smithson's intention against the misinterpretation of his wishes that would have frittered away the funds on projects remote from the donor's purpose. Henry bore testimony to his friend's ardent support at times of difficulty. Bache had a habit of avoiding discussions in which elaborate arguments were introduced, but would patiently listen until the moment arose when the difficulty of arriving at a settlement seemed apparent, and then he would intervene with a judicious suggestion that rarely failed to meet with general approval. He employed this faculty with great effect in his relations with legislators and government officials with whom he was frequently brought into contact.

The middle of the nineteenth century witnessed a surge of activity in the scientific and educational fields, but as it was also a time when intellectual labors were threatened with submergence beneath a rush of "get-rich-quick" projects, Bache fought energetically for the organization of scientists to secure recognition and to obtain results more

quickly in the scientific world. He had perceived the advantages of organization in his association with The Franklin Institute and the American Philosophical Society. He had also been an active member of the American Association for the Advancement of Science from its inception. During his term of office as president of this latter group (1850–51) he delivered an address at the Albany meeting in which he advocated the organization of scientists on a national scale which would provide a panel of qualified men from whom advisory boards could be drawn to assist government officials needing specialized assistance. With the scientists organized in a compact body they would be more effective in advancing their claims to recognition than if they acted through small special groups.

This proposal did not evoke an immediate response, but a national emergency forced it upon the government's attention during the Civil War and brought about part of the desired result.

During the period of the unhappy conflict between the states, Bache could have maintained an attitude of scientific indifference to politics had not his sense of responsibility urged him to bear a full share of the burden. As soon as the crisis was imminent, he brought in all his staff and their vessels from the South and prepared them to undertake other duties. As the regular engineer officers of the army had to be used in the line there would have been a shortage of topographical maps for the Union forces, had not the experienced men on the Coast and Geodetic Survey taken over the major part of the work of furnishing them. The coast and inlet charts they had prepared were of the utmost importance to the blockading vessels of the Navy.

Outside his office he found other employments. He served as the vice-president of the Sanitary Commission, the forerunner of the Red Cross. This was no sinecure as he had to bear the burden of responsibility for the organization of the voluntary workers and the raising of funds. He threw himself into the work with the same energy and enthusiasm that characterized everything he undertook.

Bache was frequently called into consultation by the Navy when naval operations were under discussion, and by the Army when combined operations were contemplated. At the request of the Governor of Pennsylvania he planned the defenses of Philadelphia, and he found time amid the multitude of his duties in Washington to attend personally to the supervision of the construction of the defense works.

The heads of the government were plagued during the course of the war with suggestions by patriotic but misguided persons who professed to have ideas for the conduct of hostilities. Many of these proposals were of a technical nature for which the harrassed officials had neither the time nor the qualifications to examine. Others were on the borderline between fantasy and genius which made them difficult to evaluate without an expert's knowledge of the subject. The Secretary of the

Navy was especially afflicted with these proposals, and he formed a committee comprising Bache, Joseph Henry, and Rear-Admiral C. H. Davis to whom difficult technical problems were submitted for examination and recommendations. This committee was undoubtedly able to save the government millions of dollars by preventing the adoption of plausible but impracticable proposals that could only have resulted in failure and loss.

There have been conflicting claims to the authorship of the original proposal for the foundation of the National Academy of Science, but it is generally conceded that the impulse came from Bache. He had worked consistently toward this end from the time he had introduced the idea in his Albany address. The conception crystallized at a dinner given at his home where the support of Senator Henry Wilson of Massachusetts was gained. The senator introduced the necessary bill before Congress to incorporate the Academy on the lines Bache had advocated, and President Lincoln gave his approval on the day the bill was passed.

Election to membership of the Academy was a distinction since, in Joseph Henry's words "it should be exclusively composed of men distinguished for original research, and that to be chosen one of its members would be considered a high honor." The original members met in New York in April, 1863, and elected Bache as president.

The organization of the Academy was not completed until too late for its members to give effective aid to the prosecution of the war but it had peace-time functions to discharge. Bache had always been interested in the subject of weights and measures and was inclined to favor the adoption of the metric system. At his suggestion a committee of the Academy members was appointed to make a comprehensive investigation of weights, measures, and coinages, and to make recommendations to the government if the members could suggest the introduction of any improvements to the system in use in this country. Although the matter was of deep interest to him he was unable to participate in the work of this committee.

He had developed a numbness in his fingers which distressed him and, still worse, he began to suffer from lapses of memory. However, it was his wish to continue his daily tasks and he was only prevented with difficulty from attempting to discharge his normal functions at the Survey. Failure of memory increased so rapidly that it was thought the excitement of a sea voyage and the novelty of life abroad might have a salutary effect.

Accordingly, a trip to Europe was arranged during which there were periods when his normal faculties were restored, but these became only brief flashes of his former self, and their recurrences came at longer and longer intervals. After eighteen months of travel he was brought home without hope of any permanent recovery. He survived only a few months and died at Newport, R. I. on February 17th, 1867.

Bache's principal contributions to science were in the field of geomagnetism. Apart from the three formidable volumes on the observations made at Girard College, he published several papers on terrestrial magnetism. The most extensive of these appeared in the Smithsonian *Contributions to Knowledge*, based upon unpublished material derived from these observations. His magnetic survey of Pennsylvania was the first detailed regional study of the kind made on this continent. It was a labor undertaken during his summer vacations and made entirely at his own expense. But the breadth of his scientific grasp is best revealed in the voluminous reports presented to Congress on the work of the Coast and Geodetic Survey.

The associations he formed at The Franklin Institute and the American Philosophical Society did much to broaden his interests and to develop his faculty for investigation. It seems altogether probable he would have had a distinguished career as an experimental scientist had not the appointment to the post as president to Girard College diverted his mind into other channels. Here he applied himself to the study of education and left his mark on that field of activity. Had he made it the object of his life's work, he would have become famous in the field of education. But a return to scientific work brought fresh rewards. Leadership in important scientific societies caused him to be accepted as preëminent in the world of American science.

AN OPTIMUM PURSUIT PROBLEM

BY

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ABSTRACT

The optimum thrust direction of a rocket fired from a fighter plane pursuing a constant velocity target is determined with a view towards maximizing the initial stand-off. It is shown that for flight *in vacuo* the optimum thrust direction remains constant.

INTRODUCTION

For various reasons, primarily for pilot protection, it is desirable that a fighter pilot in pursuit of a target be able to launch rockets at the greatest possible distance from the target. Since many pursuit courses occur at very high altitude, we shall consider the idealized case of flight *in vacuo*. Furthermore, the acceleration of gravity will be assumed constant. The problem is then: For a given rocket configuration, that is rocket mass, thrust magnitude, and burning time, what is the desired direction of the thrust vector in order that the initial stand-off (fighter to target range) be maximum? It is further assumed that the target flies with known, uniform velocity and that the altitude difference between pursuer and target at launch is also known. Only the case of pursuit in the vertical plane will be considered.

THEORY

Let

x, y = Cartesian coordinates of the rocket (in inertial frame)
p, q = velocity components of the rocket
v = rocket velocity (speed)
V_T = target velocity
l_1, l_2 = direction cosines of thrust vector
φ = direction angle of thrust vector
t = time
$m(t)$ = rocket mass
$T(t)$ = thrust
t_b = burning time
t_f = time of free flight
X = total horizontal range
X_f = free-flight horizontal range
g = gravitational acceleration
L = initial stand-off

Subscripts:

0 = conditions at launch
b = conditions at burn-out
i = conditions at impact

Figure 1 shows the situation under consideration. The origin of the inertial coordinate system is taken at the point of launching. The equations of motion are

$$\dot{p} = l_1 \frac{T}{m}$$

$$\dot{q} = l_2 \frac{T}{m} - g \tag{1}$$

$$p = \dot{x}$$
$$q = \dot{y}$$

[1] Michelson Laboratory, U. S. Naval Ordnance Test Station, China Lake, Calif.

and

$$l_1^2 + l_2^2 = 1. \tag{2}$$

The total horizontal range is

$$\begin{aligned} X &= x_b + X_f(y_b, p_b, q_b) \\ &= X(x_b, y_b, p_b, q_b). \end{aligned} \tag{3}$$

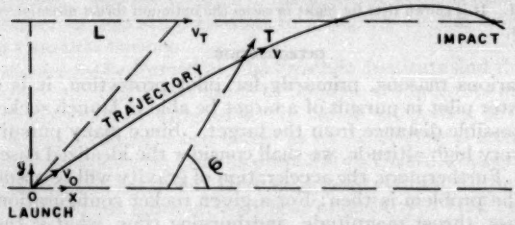

FIG. 1.

For "neighboring" trajectories[2]

$$\begin{aligned} \delta\dot{p} &= \frac{T}{m}\,\delta l_1 \\ \delta\dot{q} &= \frac{T}{m}\,\delta l_2 \\ \delta\dot{p} &= \delta\dot{x} \\ \delta\dot{q} &= \delta\dot{y} \end{aligned} \tag{4}$$

and

$$l_1\delta l_1 + l_2\delta l_2 = 0. \tag{5}$$

The initial stand-off is given by

$$\begin{aligned} L &= X - V_T(t_b + t_f) \\ &= x_b + (p_b - V_T)t_f - V_T t_b. \end{aligned} \tag{6}$$

However, the time of free flight is

$$t_f = g^{-1}[q_b \pm \sqrt{q_b^2 + 2g(y_b - y_i)}], \tag{7}$$

[2] See A. R. FORSYTH, "Calculus of Variations," New York, Cambridge University Press, 1927.

where the + sign is chosen to obtain the larger value of L, Eq. 6, since $p_b > V_T$ in order to make impact possible. Thus

$$L = L(x_b, y_b, p_b, q_b) \tag{8}$$

and in order that L be maximum[2] it is necessary that

$$\delta L = \frac{\partial L}{\partial x_b}\delta x_b + \frac{\partial L}{\partial y_b}\delta y_b + \frac{\partial L}{\partial p_b}\delta p_b + \frac{\partial L}{\partial q_b}\delta q_b = 0. \tag{9}$$

From Eq. 4

$$\begin{aligned}
\delta p_b - \delta p_0 &= \int_0^{t_b} \frac{T}{m}\,\delta l_1 dt \\
\delta q_b - \delta q_0 &= \int_0^{t_b} \frac{T}{m}\,\delta l_2 dt \\
\delta x_b - \delta x_0 &= \int_0^{t_b} (t_b - t)\frac{T}{m}\,\delta l_1 dt + t_b \delta p_0 \\
\delta y_b - \delta y_0 &= \int_0^{t_b} (t_b - t)\frac{T}{m}\,\delta l_2 dt + t_b \delta q_0.
\end{aligned} \tag{10}$$

The rocket is launched with known velocity, the velocity of the launching aircraft, that is

$$\begin{aligned}
p &= p_0 \\
q &= q_0
\end{aligned} \tag{11}$$

so that

$$\delta p_0 = \delta q_0 = 0. \tag{12}$$

Since the position of launch is fixed (origin of coordinate system),

$$\delta x_0 = \delta y_0 = 0. \tag{13}$$

Thus, Eqs. 9, 10, 12 and 13 lead to

$$\int_0^{t_b} \left\{ \left[\frac{\partial L}{\partial x_b} - \frac{l_1}{l_2}\frac{\partial L}{\partial y_b} \right](t_b - t) + \frac{\partial L}{\partial p_b} - \frac{l_1}{l_2}\frac{\partial L}{\partial q_b} \right\} \frac{T}{m}\,\delta l_1 dt = 0. \tag{14}$$

In view of the arbitrariness of δl_1, its coefficient must vanish,[2] so that

$$\frac{l_1}{l_2} \equiv \cot\varphi = \frac{(t_b - t)\dfrac{\partial L}{\partial x_b} + \dfrac{\partial L}{\partial p_b}}{(t_b - t)\dfrac{\partial L}{\partial y_b} + \dfrac{\partial L}{\partial q_b}}. \tag{15}$$

However,

$$\frac{\partial L}{\partial x_b} = 1$$

$$\frac{\partial L}{\partial y_b} = (p_b - V_T)[q_b^2 + 2g(y_b - y_i)]^{-1}$$

$$\frac{\partial L}{\partial p_b} = t_f \tag{16}$$

$$\frac{\partial L}{\partial q_b} = g^{-1}(p_b - V_T)\{1 + q_b[q_b^2 + 2g(y_b - y_i)]^{-1}\}$$

$$= t_f \frac{\partial L}{\partial y_b}$$

so that

$$\frac{l_1}{l_2} \equiv \cot \varphi = \left(\frac{\partial L}{\partial y_b}\right)^{-1} = \frac{\sqrt{q_b^2 + 2g(y_b - y_i)}}{p_b - V_T}. \tag{17}$$

From Eq. 17 it is seen that the direction of thrust is time-independent, that is, constant. Since l_1 and l_2 are time-independent

$$\begin{aligned} x_b &= A \cos \varphi + p_0 t_b \\ y_b &= A \sin \varphi + q_0 t_b - \tfrac{1}{2} g t_b^2 \\ p_b &= B \cos \varphi + p_0 \\ q_b &= B \sin \varphi + q_0, \end{aligned} \tag{18}$$

where

$$A \equiv \int_0^{t_b} (t_b - t) \frac{T}{m}\, dt$$

$$B \equiv \int_0^{t_b} \frac{T}{m}\, dt$$

so that

$$\cot \varphi = \frac{[(B \sin \varphi + q_0)^2 + 2g(A \sin \varphi + q_0 t_b - \tfrac{1}{2} g t_b^2 - y_i)]^{\frac{1}{2}}}{B \cos \varphi + p_0 - V_T}. \tag{19}$$

Finally, Eq. 6 with Eqs. 7 and 18 yields the maximum stand-off, L.

The equation for the direction of thrust, Eq. 17, expresses a necessary condition for the existence of a stationary value of the stand-off, L. It is fairly simple to show that the second variation of L is given by

$$\delta^2 L = -g\left(\frac{p_b - V_T}{V^3}\right)(t_f\delta q_b + \delta y_b)^2, \tag{20}$$

where

$$V = \sqrt{q_b^2 + 2g(y_b - y_i)}.$$

Thus $\delta^2 L < 0$ so that the value of L corresponding to the thrust direction given by Eq. 17 is indeed a maximum.

Chemical Switches.—A new type of switch to be used in the memory circuits of large computers has been announced by Mr. B. K. Green of the National Cash Register Company. Speaking at the International Symposium on the Theory of Switching, Mr. Green described the switch as incredibly tiny: a hundred million of them would fit on a surface one inch square.

Unlike previous switches, which worked mechanically (relays), or electronically (vacuum tubes and transistors), the new switch operates on chemical principles.

Mr. Green said that tiny droplets of light-sensitive fluid can be used to store information and give it up again in tiny fractions of a second. In discussing this new development, Mr. Green said "The term 'switch' may be defined as a system capable of existing in at least two stable states and capable of being changed back and forth between these states.

"The common switching principles in use today are mostly physical in nature. The switches to be discussed now are novel in that the two stable states will be provided by chemical rather than physical changes. However, just as there are no definite boundaries between chemistry and physics, so there are no definite boundaries between chemical and physical switching principles."

When certain materials are exposed to lights of different colors the material itself will change color. This process can be reversed. This phenomenon, known as "photochromism" provides the two stable states required for switching action. When these photochromic materials are used in solution, they may be enclosed in the form of tiny droplets by capsules or cellular structures. An automatic process has been developed to produce many thousands of billions of these cells in a single batch operation. Each of these cells is a switching unit, about two and one-half microns in diameter. They can be made in single layers containing about 100 million per square inch, although Mr. Green stated that the practical limits may be somewhat lower.

These switches may be changed from one state to another in about one one-thousandth of a second. Three different colors of light may be used to read, write, and erase the information in these synthetic memory cells, so that the reading process does not destroy the information in the cells by changing their color.

In discussing the chemical nature of the new switch, Mr. Green said "Many analogies have been drawn between the human brain and man-made machines. Generally, these analogies tend to ignore the chemical aspects of the brain and lay chief emphasis on the physical or circuitry-network aspects. I do not intend to stress these analogies, but merely state that we are working with new components. Basically, these are extremely different from conventional components, and much more closely allied to neuron and brain structures than are transistors, diodes, and magnetic cores, although it is not our intention to duplicate a neuron or a brain."

ROTATING DISKS WITH NO PLANE OF SYMMETRY *

BY

P. G. HODGE, JR.[1] AND JOHN PAPA[2]

ABSTRACT

The state of stress in a rotating disk with no plane of symmetry perpendicular to the axis of rotation is investigated. Due to the variation of centroidal heights with respect to the radius, bending moments are induced in addition to the usual radial and tangential forces.

The problem is defined in terms of direct stress and bending resultants in the radial and tangential directions, together with the extension and rotation of the centroidal surface. It is then reduced to the solution of two simultaneous second order linear equations for two stress functions. Various methods of solution are presented and illustrated in an example.

1. INTRODUCTION

The problem of determining the stresses in a rotating disk with a plane of symmetry normal to the axis of rotation has been extensively investigated and an abundant amount of literature on the subject is available.[3]

If the rotating disk is axisymmetric but has no plane of symmetry normal to the axis of rotation, the basic assumption made in previous investigations (that the stresses at any radius are constant over the thickness) is unrealistic. To see this qualitatively, we may consider the disk whose profile is shown in Fig. 1. It is evident that across an arbitrary section AB, the material beyond AB will exert not only a centrifugal force, but also a resultant bending moment about the center of AB. A similar investigation of a rotating non-symmetric ray (2)[4] showed that bending effects could be of considerable importance. The present investigation, then, is concerned with a first approximation to account for this bending in the case of disks.

The basic equations are derived in the next section, after first stating the relevant assumptions. These equations turn out to contain the direct stress and bending resultants in the radial and circumferential directions, together with the radial extension and rotation of the reference plane. It is shown that these can be reduced to a pair of equations containing only the displacement variables, or to a different pair con-

* The theory underlying this paper was developed while one of the authors (PGH) was Consultant to AiResearch Manufacturing Company, Los Angeles. Permission to publish these results is gratefully acknowledged. The complete paper is part of a thesis submitted by the other author (JP) in partial fulfillment of the requirements for the degree of Master of Science in Applied Mechanics at the Polytechnic Institute of Brooklyn.

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[3] See, for instance, Reference 1, which contains several further references.

[4] The boldface numbers in parentheses refer to the references appended to this paper.

taining only two stress functions. Only the latter approach is considered in detail.

In Sections 3 and 4 an analytic solution of these equations is obtained for a particular class of disk profiles, and applied to an example. Pertinent results are presented graphically.

The remainder of the paper is concerned with alternative methods of solution. In particular, Section 5 generalizes a technique first used by Manson (3), while Section 6 is concerned with an iterative procedure, based upon the corresponding symmetric disk as an original approximation.

Finally, the conclusions of the paper will be discussed in Section 7.

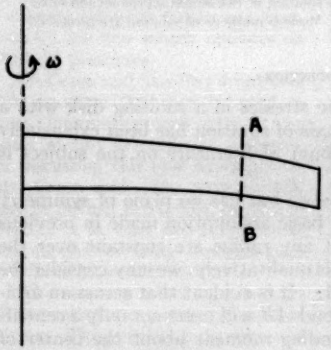

FIG. 1. Example of a non-symmetric disk.

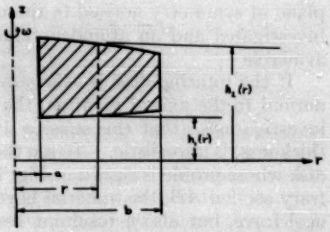

FIG. 2. Arbitrary non-symmetric disk.

2. BASIC EQUATIONS

In the derivation of the basic equations, it is assumed that shear and axial stresses are small and may be neglected. Also, linear elements parallel to the axis of rotation are assumed to remain linear. Since the material is assumed to satisfy Hooke's Law, this implies that the stresses are linear across the thickness of the disk. Further, the deformations are assumed to be small, so that all loads may be applied to the undeformed disk. Finally, the weight of the disk is neglected, and the only forces acting upon it are those induced by rotation.

Starting with these assumptions, we consider the disk shown in Fig. 2, rotating about the z axis with an angular speed ω. We define the mean height $\bar{h}$ and the thickness h of the disk by

$$\bar{h}(r) = (1/2)[h_1(r) + h_2(r)], \tag{1}$$

$$h(r) = h_2(r) - h_1(r), \tag{2}$$

where h_1 and h_2 are the top and bottom surfaces, respectively.

The equilibrium of the disk will be expressed in terms of the direct stresses T_r and T_θ acting upon an element (Fig. 3), and the bending moments M_r and M_θ computed about the mean height $\bar{h}$. Also acting upon the element will be a body force F due to the motion. Due to axial symmetry, all quantities are functions only of the radial distance r, and

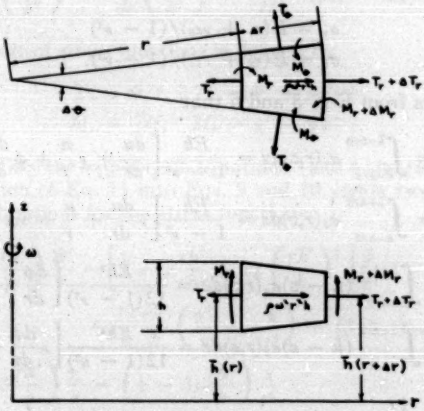

FIG. 3. Equilibrium of an element.

we need consider equilibrium only in the radial direction. Equating the radial components of force we are led to

$$d(rT_r)/dr - T_\theta + \rho\omega^2 r^2 h = 0 \tag{3}$$

while moment equilibrium is expressed by

$$d(rM_r)/dr - M_\theta r T_r \, d\bar{h}/dr = 0. \tag{4}$$

These equations were previously obtained by Hodge (2), but no use was made of them. Since the moments have no effect upon the force equilibrium, Eq. 3 is, of course, the usual equilibrium equation for rotating disks.

Next, we consider the displacement of a linear element which was initially parallel to the z axis. Let $u(r)$ be the radial displacement of the centroid, and let $\phi(r)$ be the angle through which it is rotated, Fig. 4. The total radial displacement of the particle, initially at r, z is then given by

$$u_r(r,z) = u(r) - [z - \bar{h}(r)]\phi(r)$$

and the strains are

$$\epsilon_r = \partial u_r/\partial_r = du/dr(z - \bar{h})d\phi/dr + \phi d\bar{h}/dr$$
$$\epsilon_\theta = u_r/r = u/r - (z - \bar{h})\phi/r. \tag{5}$$

Since the axial stress is neglected, Hooke's Law may be written as

$$\sigma_r = E(\epsilon_r + \nu\epsilon_\theta)/(1 - \nu^2)$$
$$\sigma_\theta = E(\epsilon_\theta + \nu\epsilon_r)/(1 - \nu^2). \tag{6}$$

It then follows from Eqs. 5 and 6 that

$$T_r = \int_{\bar{h}-h/2}^{\bar{h}+h/2} \sigma_r(r,z)dz = \frac{Eh}{1-\nu^2}\left[\frac{du}{dr} + \nu\frac{u}{r} + \phi\frac{d\bar{h}}{dr}\right]$$
$$T_\theta = \int_{\bar{h}-h/2}^{\bar{h}+h/2} \sigma_\theta(r,z)dz = \frac{Eh}{1-\nu^2}\left[\nu\frac{du}{dr} + \frac{u}{r} + \nu\phi\frac{d\bar{h}}{dr}\right] \tag{7}$$

$$M_r = \int_{\bar{h}-h/2}^{\bar{h}+h/2} (\bar{h} - z)\sigma_r(r,z)dz = \frac{Eh^3}{12(1-\nu^2)}\left[\frac{d\phi}{dr} + \nu\frac{\phi}{r}\right]$$
$$M_\theta = \int_{\bar{h}-h/2}^{\bar{h}+h/2} (\bar{h} - z)\sigma_\theta(r,z)dz = \frac{Eh^3}{12(1-\nu^2)}\left[\nu\frac{d\phi}{dr} + \frac{\phi}{r}\right]. \tag{8}$$

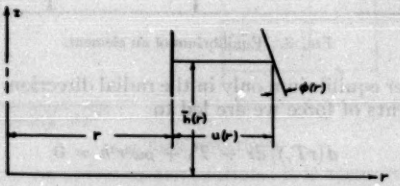

FIG. 4. Displacement of an element.

Equations 3, 4, 7 and 8 represent six equations in the six unknowns T_r, T_θ, M_r, M_θ, u, and ϕ. Together with suitable boundary conditions they provide a determinate problem for the resultants, displacement, and rotation. They may be reduced to a set of two second-order equations by either of the same techniques which are useful in symmetric disk problems. Obviously, the substitution of Eqs. 7 and 8 into Eqs. 3 and 4 yields two second order equations for u and ϕ. However, since the boundary conditions are usually not given in terms of displacements, the resulting equations are generally not as useful as stress equations would be. A method of obtaining these latter equations is to treat Eqs. 7 and 8 as linear algebraic equations, solve for u/r, u', ϕ/r, ϕ', and eliminate u and ϕ. This leads to

$$\frac{d}{dr}\left(\frac{T_\theta}{h}\right) - \nu\frac{d}{dr}\left(\frac{T_r}{h}\right) - \frac{1+\nu}{rh}(T_r - T_\theta) + \frac{12h'}{h^3}(M_\theta - \nu M_r) = 0 \quad (9)$$

$$\frac{d}{dr}\left(\frac{M_\theta}{h^3}\right) - \nu\frac{d}{dr}\left(\frac{M_r}{h^3}\right) - \frac{1+\nu}{rh^3}(M_r - M_\theta) = 0. \quad (10)$$

Next, a pair of stress functions is defined by

$$\begin{aligned} T_r &= \Psi/r, \quad T_\theta = \Psi' + \rho\omega^2 r^2 h, \\ M_r &= \chi/r, \quad M_\theta = \chi' - \Psi h' \end{aligned} \quad (11)$$

in order to satisfy the equilibrium equations 3 and 4 identically. Finally the substitution of Eq. 11 into Eqs. 9 and 10 yields two second-order differential equations for the stress functions.

$$\begin{aligned} \Psi'' + \left(1 - \frac{rh'}{h}\right)\frac{\Psi'}{r} - \left[1 - \nu\frac{rh'}{h} + 12\left(\frac{rh'}{h}\right)^2\right]\frac{\Psi}{r^2} \\ + \frac{12}{h}\frac{rh'}{h}\left(\frac{\chi'}{r} - \nu\frac{\chi}{r^2}\right) + (3+\nu)\rho\omega^2 rh = 0 \\ \chi'' + \left(1 - 3\frac{rh'}{h}\right)\frac{\chi'}{r} - \left(1 - 3\nu\frac{rh'}{h}\right)\frac{\chi}{r^2} \\ - rh'\left[\frac{\Psi'}{r} + \left(1 + \nu - 3r\frac{h'}{h} + r\frac{h''}{h'}\right)\frac{\Psi}{r^2}\right] = 0. \end{aligned} \quad (12)$$

Equations 12 are generally similar to the defining equation

$$\Psi'' + \left(1 - \frac{rh'}{h}\right)\frac{\Psi'}{r} - \left(1 - \nu\frac{rh'}{r}\right)\frac{\Psi}{r^2} + (3+\nu)\rho\omega^2 rh = 0 \quad (13)$$

encountered in the theory of symmetric rotating disks, and to a similar equation in the theory of bending of plates. Therefore it is reasonable to hope that many of the techniques used in these connections will be useful here. Among profiles for which this has been done for symmetric shapes under bending or rotation may be mentioned Föppl's solution in closed form (4) for $h = h_0 r^n$, Gran Olsson's solution as a hypergeometric series (5) for $h = h_0(1 - r)^n$, and Pichler's solution as an infinite series (6) for $h = h_0 e^{-\beta r^2/6}$.

3. ANALYTIC SOLUTION

If the surfaces of the disk can be written as power functions of r, Eq. 12 can be solved in closed form. For simplicity, it will be assumed that one surface is flat, hence we take $h_1 = 0$, $h_2 = 2cr^n$.

It then follows from Eqs. 1 and 2 that

$$h = 2cr^n, \quad \bar{h} = cr^n. \tag{14}$$

The substitution of Eqs. 14 into Eqs. 12 yields

$$\Psi'' + (1-n)\Psi'/r - (1 - n\nu - 3n^2)\Psi/r^2 + (3n/cr^n) \times (\chi'/r - \nu\chi/r^2) = -2c\rho\omega^2(3+\nu)r^{n+1} \tag{15}$$

$$\chi'' + (1-3n)\chi'/r - (1-3n\nu)\chi/r^2 - ncr^n \times [\Psi'/r - (2n-\nu)\Psi/r^2] = 0. \tag{16}$$

The complementary solution of Eqs. 15 and 16 is found by trying

$$\Psi = Ar^\alpha \qquad \chi = Br^{n+\alpha}. \tag{17}$$

Substituting Eq. 17 into the homogeneous equations corresponding to Eqs. 15 and 16, we see that A and B must satisfy

$$\begin{aligned} (\alpha^2 - n\alpha - 1 + n\nu - 3n^2)A + (3n\alpha + 3n^2 - 3n\nu)(B/c) &= 0, \\ (-n\alpha + 2n^2 - n\nu)A + (\alpha^2 - n\alpha - 2n^2 + 3n\nu - 1)(B/c) &= 0. \end{aligned} \tag{18}$$

These equations will have a non-trivial solution only if the determinant of the coefficients vanishes. Therefore α must satisfy

$$\alpha^4 - 2n\alpha^3 - (2+n^2)\alpha^2 + 2(1+n^2)n\alpha + (1+5n^2) + 2n\nu(2\alpha^2 - 2n\alpha - 2 - n^2) = 0. \tag{19}$$

The complete complementary solution may then be written as

$$\Psi = \sum_{k=1}^{4} A_k r^{\alpha_k}, \quad \chi = \sum_{k=1}^{4} B_k r^{n+\alpha_k}, \tag{20}$$

where α_k are the four roots of Eq. 19, and A_k and B_k are related by either of Eqs. 18 with $\alpha = \alpha_k$.

To Eqs. 20 must be added the particular solution which will be of the form

$$\Psi = \beta r^{n+3} \qquad \chi = \gamma r^{2n+3}. \tag{21}$$

Substituting Eq. 21 into Eqs. 15 and 16, we see that β and γ must be given by

$$\beta = -2c\rho\omega^2(-2n^2 + 3n + 8 + 3n\nu)\Delta \tag{22}$$

$$\gamma = -2nc^2\rho\omega^2(-n + 3 + \nu)\Delta, \tag{23}$$

where

$$\Delta = (3+\nu)[(-6n^3 - 4n^2 + 48n + 64) + n\nu(-2n^2 + 12n + 32)]^{-1}. \tag{24}$$

The constants A_1, A_2, A_3, A_4 appearing in Eqs. 20 are to be determined from the boundary conditions. At $r = b$ (the outer radius) the radial force and moment will be prescribed, so that, in view of Eqs. 11,

$$\Psi(b) = \Psi^* \qquad \chi(b) = \chi^*, \tag{25}$$

where Ψ^* and χ^* are known. If there are no "bucket loads," then Ψ^* and $\chi^* = 0$. For a disk with a central hole of radius a, the same reasoning shows that

$$\Psi(a) = \chi(a) = 0. \tag{26}$$

On the other hand, for a solid disk, $T_r = T_\theta$ and $M_r = M_\theta$ at the center so that, by Eq. 11

$$\begin{aligned} &\lim_{r\to 0} [\Psi(r)/r - \Psi'(r)] = 0 \\ &\lim_{r\to 0} [\chi(r)/r - \chi'(r) + \Psi(r)h'(r)] = 0. \end{aligned} \tag{27}$$

4. EXAMPLE

As a particular example, let us consider the disk whose dimensions are shown in Fig. 5. For definiteness, Poisson's ratio will be assigned the value $\nu = 1/4$.

The disk is divided into two regions, the flat and curved regions, which we shall designate as A and B, respectively. Region A is a trivial case of a power function with $c = 25/64$, $n = 0$; in region B, $c = 25/16$, $n = -2$.

It is readily verified that the functions

$$\Psi_{comp} = \left[5Ar + 3B/r^3 + (13 - 4\sqrt{10})\frac{K}{r}\left(\frac{r}{2}\right)^{\sqrt{10}} + (13 + 4\sqrt{10})\frac{L}{r}\left(\frac{2}{r}\right)^{\sqrt{10}}\right]\rho\omega^2 \tag{28}$$

$$\chi_{comp} = \frac{25}{16r^2}\left[7Ar + \frac{B}{r^3} + \frac{3K}{r}\left(\frac{r}{2}\right)^{\sqrt{10}} + \frac{3L}{r}\left(\frac{2}{r}\right)^{\sqrt{10}}\right]\rho\omega^2$$

constitute a complete complementary solution in region B. However, Eqs. 21, 22, 23 and 24, cannot be used to find the particular solution in this case ($n = -2$), since $\Psi = r$ is part of the complementary solution. Indeed, if we set ($n = -2$) in Eq. 24 we obtain $\Delta = \infty$. However, we may seek a particular solution of the form

$$\Psi_{part} = (P + Q \ln r)r, \quad \chi_{part} = T \ln r/r. \tag{29}$$

Substitution of Eqs. 29 into Eqs. 15 and 16 then determines P, Q, and T.

Finally, then, the stress functions in region B of the disk are given by

$$\Psi_B = \Psi_{comp} + \left[\frac{325}{128} r \left(\frac{19}{21} - \frac{5}{4} \ln r\right)\right] \rho\omega^2 \tag{30}$$

$$\chi_B = \chi_{comp} - \frac{25}{16r^2}\left[\left(\frac{2275}{512}\right) r \ln r\right] \rho\omega^2. \tag{31}$$

In Region A of the disk, the substitution of the parameters into Eqs. 15 and 16 leads to

$$\begin{aligned} &\Psi'' + \Psi'/r - \Psi/r^2 + \left(\frac{325}{128}\right) \rho\omega^2 r = 0, \\ &\chi'' + \chi'/r - \chi/r^2 = 0. \end{aligned} \tag{32}$$

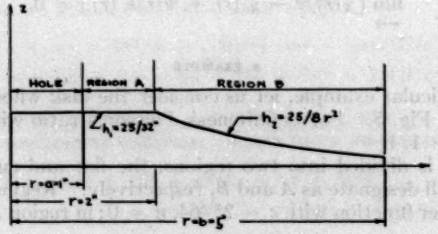

FIG. 5. Illustrative disk.

The general solution to these equations is easily seen to be

$$\begin{aligned} \Psi_A &= [Dr + F/r - (325/1024)r^3]\rho\omega^2 \\ \chi_A &= [Gr + H/r]\rho\omega^2. \end{aligned} \tag{33}$$

The eight arbitrary constants in Eqs. 30, 31 and 33 may be determined from the boundary and continuity conditions. No loads or moments are applied at either edge, and at $r = 2$, all forces and moments must be continuous. Substitution of Eqs. 30, 31 and 33 into these eight conditions leads to a set of simultaneous algebraic equations. For the particular disk dimensions given in Fig. 5, these equations were solved by the Crout method (7) the results being

$$\begin{aligned} A &= 0.482540 & L &= 0.199392 \\ B &= -11.793999 & D &= 3.893594 \\ K &= 1.742227 & G &= 0.529665 \\ F &= 3.576211 & H &= -0.529665 \end{aligned} \tag{34}$$

The stress resultants are now found immediately from Eqs. 30, 31, 33 and 11. Typical results are shown in Figs. 6 and 7.

For design purposes it is usually desirable to know the actual stresses throughout the disk. Based on the assumption of linearity, these are completely determined by the stresses on the top and bottom surface,

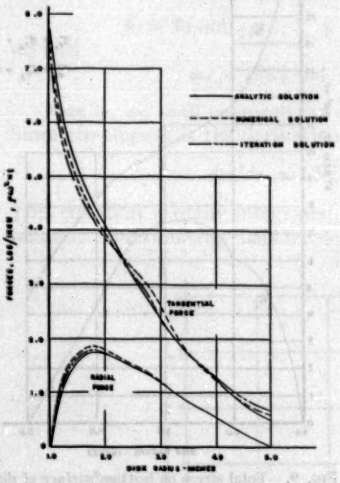

FIG. 6. Tangential and radial forces.

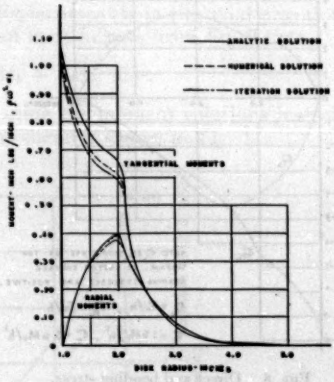

FIG. 7. Tangential and radial moments.

σ_{r_1}, σ_{θ_1}, and σ_{r_2}, σ_{θ_2}, respectively. These, in turn, may be conveniently expressed in terms of direct and bending stresses defined by

$$\begin{aligned} \sigma_{r_d} &= T_r/h, & \sigma_{\theta_d} &= T_\theta/h \\ \sigma_{r_b} &= 6M_r/h^2, & \sigma_{\theta_b} &= 6M_\theta/h^2. \end{aligned} \tag{35}$$

The surface stresses are then given by

$$\begin{aligned} \sigma_{r_1} &= \sigma_{r_d} + \sigma_{r_b}, & \sigma_{r_2} &= \sigma_{r_d} - \sigma_{r_b} \\ \sigma_{\theta_1} &= \sigma_{\theta_d} + \sigma_{\theta_b}, & \sigma_{\theta_2} &= \sigma_{\theta_d} - \sigma_{\theta_b}. \end{aligned} \tag{36}$$

Typical results are shown in Figs. 8, 9 and 10.

A further quantity of interest to the designer is the maximum speed ω_e for which the disk remains fully elastic. Assuming for simplicity that the material of the disk will yield according to the Tresca yield condition,

$$\tau_{\max} = k, \tag{37}$$

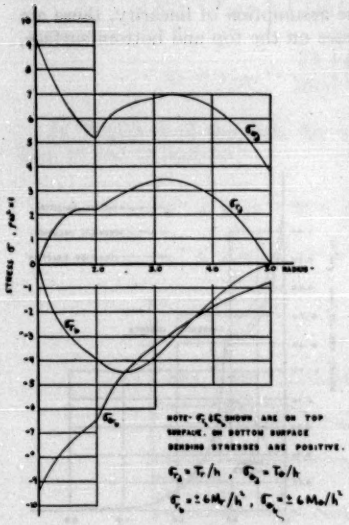
STRESS σ , psi
DISK RADIUS - INCHES
NOTE- σr & σθ SHOWN ARE ON TOP SURFACE. ON BOTTOM SURFACE BENDING STRESSES ARE POSITIVE.
σr2 = Tr/h , σθ2 = Tθ/h
σr1 = ± 6Mr/h² , σθ1 = ± 6Mθ/h²

FIG. 8. Direct and bending stress.

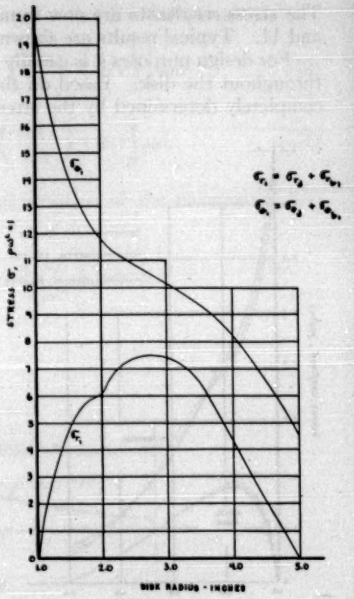

FIG. 9. Total stress on bottom surface of disk.

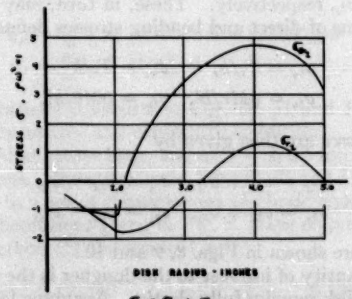

FIG. 10. Total stress on top surface of disk.

we see from Fig. 9 that this will first occur at the bottom of the inner edge. At that point

$$\tau_{max} = \frac{\sigma_\theta}{2} = 9.87/\rho\omega^2. \tag{38}$$

Assuming the values

$$k = 30{,}000 \text{ psi.}, \qquad \rho = 0.772 \times 10^{-3} \text{ slugs/in}^3 \tag{39}$$

we find

$$\omega_e = 1982 \text{ rad/sec} = 18{,}945 \text{ rpm}. \tag{40}$$

Finally, we shall compute the displacement w in the axial direction. Since the slope ϕ is the derivative of w, it follows from Eq. 9 that

$$dw/dr = 12r(M_\theta - \nu M_r)/Eh^3. \tag{41}$$

This equation is easily integrated, using the moment solutions just obtained. The resulting displacement curve is shown in Fig. 11.

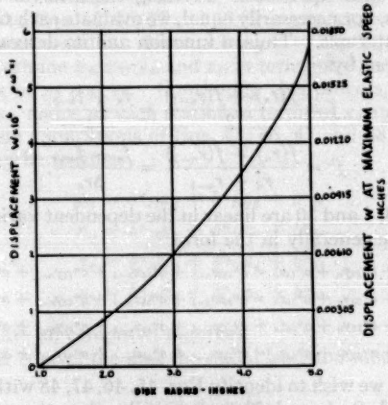

FIG. 11. Disk displacement w.

Obviously w is a maximum at the outer edge, and increases with the speed. Therefore, the maximum elastic displacement will occur at $r = b$ when $\omega = \omega_e$. In view of Eq. 40, the resulting displacement turns out to be

$$W_{max} = 5.727 \times 10^{-6}\rho\omega^2 = 0.0174 \text{ in.} \tag{42}$$

Since this is small compared to the thickness of the disk at that point ($w/h = 0.139$), small deflection theory is applicable for this disk within the speeds for which the stresses are elastic.

5. NUMERICAL METHOD OF SOLUTION

The solution just given is evidently laborious to obtain even in the case of a relatively simple disk profile. Further the method is useless unless $h = 2cr^n$. Therefore, it is desirable to investigate other possible methods of solution. Manson (3) has given a method of solving the symmetric disk in the case of arbitrary thickness, including thermal stresses and variation of elastic coefficients with temperature. His method can be generalized to include the same temperature effects in our case. However, for simplicity of exposition we shall here consider only the constant temperature situation.

The method is based upon a direct numerical integration of Eqs. 3, 4 and 10. Since subscripts will be used to denote position in the exposition to follow, we shall rename the dependent variables:

$$T_r = w, \quad T_\theta = x, \quad M_r = y, \quad M_\theta = z. \tag{43}$$

Also, we shall replace the differential equations 3, 4 and 10 by corresponding difference equations. Dividing the interval $a < r < b$ into N sub-intervals, not necessarily equal, we evaluate each term at the midpoints of the intervals. Thus, a function and its derivation in the nth interval are given by

$$f = \frac{f(r_n) + f(r_{n-1})}{2} = \frac{f_n + f_{n-1}}{2}$$

$$f' = \frac{f(r_n) - f(r_{n-1})}{r_n - r_{n-1}} = \frac{f_n - f_{n-1}}{\Delta r_n}. \tag{44}$$

Since Eqs. 3, 4 and 10 are linear in the dependent variables they may be written quite generally in the form

$$a^n_{11}w_n + a^n_{12}x_n + a^n_{13}y_n + a^n_{14}z_n = a^n_{15}w_{n-1} + a^n_{16}x_{n-1} + a^n_{17}y_{n-1} + a^n_{18}z_{n-1} + a^n_{19} \tag{45}$$

$$a^n_{21}w_n + a^n_{22}x_n + a^n_{23}y_n + a^n_{24}z_n = a^n_{25}w_{n-1} + a^n_{26}x_{n-1} + a^n_{27}y_{n-1} + a^n_{28}z_{n-1} + a^n_{29} \tag{46}$$

$$a^n_{31}w_n + a^n_{32}x_n + a^n_{33}y_n + a^n_{34}z_n = a^n_{35}w_{n-1} + a^n_{36}x_{n-1} + a^n_{37}y_{n-1} + a^n_{38}z_{n-1} + a^n_{39} \tag{47}$$

$$a^n_{41}w_n + a^n_{42}x_n + a^n_{43}y_n + a^n_{44}z_n = a^n_{45}w_{n-1} + a^n_{46}x_{n-1} + a^n_{47}y_{n-1} + a^n_{48}z_{n-1} + a^n_{49} \tag{48}$$

In particular, if we wish to identify Eqs. 45, 46, 47, 48 with the difference forms of Eqs. 3, 9, 4, and 10, respectively, then the a^n_{ij} are given in terms of the parameters of the disk by

$$a^n_{11} = r_n/\Delta r$$
$$a^n_{12} = -1/2$$
$$a^n_{13} = 0$$
$$a^n_{14} = 0$$

$$a^n_{15} = r_{n-1}/\Delta r_n$$
$$a^n_{16} = 1/2$$
$$a^n_{17} = 0$$
$$a^n_{18} = 0$$
$$a^n_{19} = -1/2\rho\omega^2(r_n{}^2h_n + r_{n-1}{}^2h_{n-1})$$

$$a^n_{21} = -\nu/h_n\Delta r_n - (1+\nu)/2r_nh_n$$
$$a^n_{22} = 1/h_n\Delta r_n + (1+\nu)/2r_nh_n$$
$$a^n_{23} = -6\nu(h_n - h_{n-1})/h_n{}^2\Delta r_n$$
$$a^n_{24} = 6(h_n - h_{n-1})/h_n{}^2\Delta r_n$$

$$a^n_{25} = -\nu/h_{n-1}\Delta r_n + (1+\nu)/2r_{n-1}h_{n-1}$$
$$a^n_{26} = 1/h_{n-1}\Delta r_n - (1+\nu)/2r_{n-1}h_{n-1}$$
$$a^n_{27} = 6\nu(h_n - h_{n-1})/h_{n-1}{}^2\Delta r_n$$
$$a^n_{28} = -6(h_n - h_{n-1})h_{n-1}{}^2\Delta r_n$$
$$a^n_{29} = 0$$

$$
\begin{aligned}
a^n_{21} &= -1/2r_n(\bar{h}_n - \bar{h}_{n-1})\Delta r_n & a^n_{25} &= 1/2r_{n-1}(\bar{h}_n - \bar{h}_{n-1})\Delta r_n \\
a^n_{22} &= 0 & a^n_{26} &= 0 \\
a^n_{23} &= r_n/\Delta r_n & a^n_{27} &= r_{n-1}/\Delta r_n \\
a^n_{24} &= -1/2 & a^n_{28} &= 1/2 \\
 & & a^n_{29} &= 0 \\
a^n_{41} &= 0 & a^n_{45} &= 0 \\
a^n_{42} &= 0 & a^n_{46} &= 0 \\
a^n_{43} &= -\nu/h_n{}^3\Delta r_n - (1+\nu)/2r_n h_n{}^3 & a^n_{47} &= -\nu/h_{n-1}{}^3\Delta r_n + (1+\nu)/2r_{n-1}h_{n-1}{}^3 \\
a^n_{44} &= 1/h_n{}^3\Delta r_n + (1+\nu)/2r_n h_n{}^3 & a^n_{48} &= 1/h_{n-1}{}^3\Delta r_n - (1+\nu)/2r_{n-1}h_{n-1}{}^3 \\
 & & a^n_{49} &= 0
\end{aligned}
$$

For definiteness in presenting the method, we shall as in Section 4, consider a disk with a finite circular hole at the center, although the method is readily extended to the solid disk. At the boundary $r = a$ of the hole, the radial resultants are both zero. Therefore,

$$w_0 = y_0 = 0. \tag{49}$$

Thus there exist only two unknowns x_0 and z_0 at the inner edge. Therefore, setting $n = 1$ in Eqs. 45, 46, 47, 48 and knowing the parameters a^n_{ij}, we may solve Eqs. 45, 46, 47 and 48 for w_1, x_1, y_1, and z_1, in terms of the two unknowns x_0 and z_0. Next, setting $n = 2$ in Eqs. 45, 46, 47 and 48, we may determine w_2, x_2, y_2, and z_2, in terms of w_1, x_1, y_1, and z_1 and hence in terms of x_0 and z_0. Continuing this process, we obtain the values w_n, x_n, y_n, and z_n at each station in terms of x_0 and z_0. Further, since each of the applications of Eqs. 45, 46, 47 and 48 is linear, these expressions may be written

$$
\begin{aligned}
w_n &= b^n_{16}x_0 + b^n_{26}z_0 + b^n_{36} \\
x_n &= b^n_{16}x_0 + b^n_{26}z_0 + b^n_{36} \\
y_n &= b^n_{17}x_0 + b^n_{27}z_0 + b^n_{37} \\
z_n &= b^n_{18}x_0 + b^n_{28}z_0 + b^n_{38},
\end{aligned} \tag{50}
$$

where the b^n_{ij} are all computed numbers.

At the outer edge of the disk the radial load and moment are zero so that

$$w_N = y_N = 0. \tag{51}$$

Therefore, it is readily seen that x_0 and z_0 are found by the solution of

$$
\begin{aligned}
b^N_{16}x_0 + b^N_{26}z_0 + b^N_{36} &= 0 \\
b^N_{17}x_0 + b^N_{27}z_0 + b^N_{37} &= 0.
\end{aligned} \tag{52}
$$

Having found x_0 and z_0 from the solution of Eqs. 52, it is obvious that Eqs. 50 will yield explicit values of w, x, y, and z at any point n.

For the particular disk shown in Fig. 5, 11 points were taken at the values r = 1.0, 1.6, 1.8, 2.0, 2.2, 2.4, 3.0, 4.0, 4.5, 4.8, 5.0. The com-

puted resultants are shown in Figs. 6 and 7. Comments on the accuracy of the solution will be reserved for the final section.

6. ITERATION METHOD OF SOLUTION

In cases where the effect of bending is not of too great a significance, the following successive approximation technique may be of some value. As a first approximation, we assume that there is no bending. With $\phi = 0$, Eqs. 3 and 7 are then the usual equations for symmetric rotating disks, and can be solved by any of the standard methods. In particular, the function T_r can be determined. With T_r known, however, Eqs. 3, 4, 7 and 8 are the usual equations for the bending of a circular plate with variable thickness (8, Sec. 15), if we identify the quantity $-T_r d\bar{h}/dr$ occurring in Eq. 4 with the applied shearing force per unit length. Therefore, this problem can be solved by known techniques and, in particular, the rotation ϕ can be determined as a known function of r. Using this value of ϕ, we can obtain an improved solution for the centrifugal forces. To this end, we define modified stress resultants

$$t_r = T_r - v \qquad t_\theta = T_\theta - v, \tag{53}$$

where $v = E\phi h\bar{h}'/(1 - \nu^2)$ is a known function. The substitution of Eqs. 43 into Eqs. 3 and 9 leads to

$$\begin{aligned} t_r &= [Eh/(1 - \nu^2)](u' + \nu u/r) \\ t_\theta &= [Eh/(1 - \nu^2)](\nu u' + u/r) \\ (rt_r' - t_\theta + r[v' + (1 - \nu)v/r + \rho\omega^2 rh] &= 0 \end{aligned} \tag{54}$$

which are of the same form as Eqs. 3 and 9 provided we identify the entire term in brackets as the body force.

This iteration can be carried out by either analytic or numerical methods. In the latter case, advantage can be taken of the fact, first pointed out by Föppl (4), that the plate equation is mathematically equivalent to the symmetric rotating disk equation. To see this, let us

TABLE I.

Problem	Symmetric Rotating Disk	Bent Circular Plate	Analogy
Equations	54	4, 10	55
Radial Resultant	t_r	M_r	η
Tangential Resultant	t_θ	M_θ	ζ
Displacement	u	ϕ	ξ
Thickness Function	h	$h^3/12$	w
Nonhomogeneous Term	$[v' + (1 - \nu)v/r + \rho\omega^2 rh]$	$-T\bar{h}'$	P
Elastic Constants	$E/(1 - \nu^2)$	$E/(1 - \nu^2)$	α

make the substitutions defined in Table I. That is, in Eqs. 3 and 7 we replace t_r by η, t_θ by ζ, etc., to obtain

$$\begin{aligned} \eta &= \alpha w(\xi' + \nu\xi/r) \\ \zeta &= \alpha w(\nu\xi' + \xi/r) \\ (r\eta)' &- \zeta + rP = 0. \end{aligned} \tag{55}$$

Equally, if we replace M_r by η, M_θ by ζ, etc. in Eqs. 4 and 8, we again obtain Eq. 55. Therefore, each of the iterations can be handled on the same computing form.

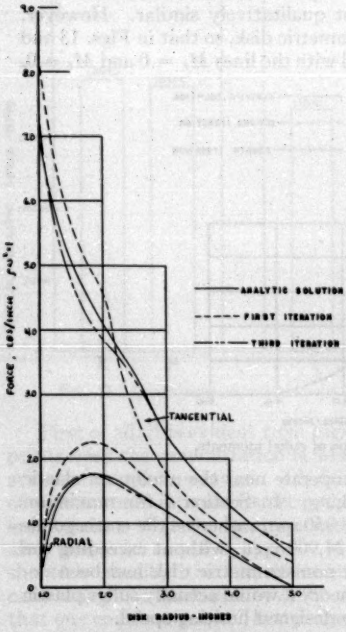

FIG. 12. Comparison of forces.

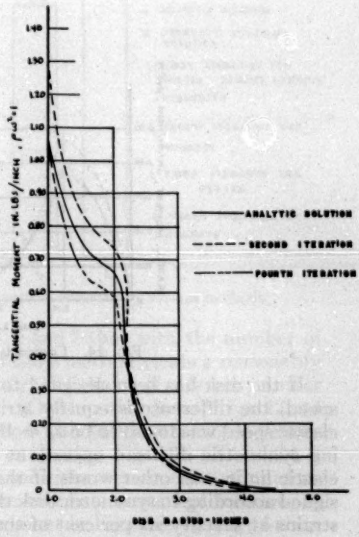

FIG. 13. Comparison of tangential moments.

For the particular disk under investigation, Manson's numerical method was used to obtain the zero approximation for forces and moments and a first improvement for each. The results are shown in Figs. 12, 13 and 14, and will be commented on in the concluding section.

7. CONCLUSIONS

A solution for the rotating disk with no plane of symmetry normal to the axis of rotation has been presented. The results of a particular example indicate that at the point of maximum shear stress (the inner boundary), the stress due to bending is of the same order of magnitude as the stress due to tangential force. The importance of considering bending cannot then be minimized in the stress analysis of this type disk where moments are induced.

To illustrate this, let us compare the results when bending is considered with the results if bending is neglected. This latter is equivalent to the first step of the iteration procedure described in Section 6. Therefore the direct stresses are compared by the solid and dashed curves in Fig. 12, and are seen to be at least qualitatively similar. However, there are no bending stresses in a symmetric disk, so that in Figs. 13 and 14 the solid curves must be compared with the lines $M_r = 0$ and $M_\theta = 0$.

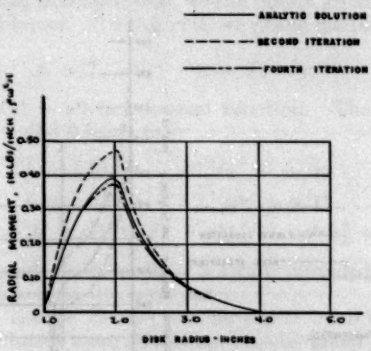

FIG. 14. Comparison of radial moments.

If the disk has been designed to operate near the maximum elastic speed, the difference is equally striking. In Section 4 the maximum elastic speed was found to be $\omega_* = 18{,}950$ rpm., whereas the corresponding symmetric disk can operate at 24,900 rpm. without exceeding the elastic limit. In other words, if the non-symmetric disk had been designed according to symmetric disk theory it would actually suffer plastic strains at seventy six per cent of the designed limiting speed.

A further comparison is obtained from Fig. 11 for the axial displacement w. This, of course, is zero for the symmetric disk. When operating at 18,950 rpm., the displacement at the rim is 0.0174 in. While this is small compared to the thickness of the disk, it may be of the order of magnitude of the design clearance between the disk and its housing. Thus it may be necessary to compute this displacement in order to be sure that there will still be clearance at top speed. If the disk is oper-

ated at the 24,900 rpm. permitted by symmetric theory, then the actual displacement would be even larger than the 0.030 in. predicted by Eq. 42, since the additional strain would be partially plastic.

If it is agreed that the non-symmetric character of the disk must be accounted for, there remains the problem of the best method of doing this. The analytic solution presented here is applicable only when the disk profile can reasonably be approximated by power functions of the radius, and even so leads to rather laborious computations. Therefore, it is of interest to compare this exact solution with the various numerical methods used.

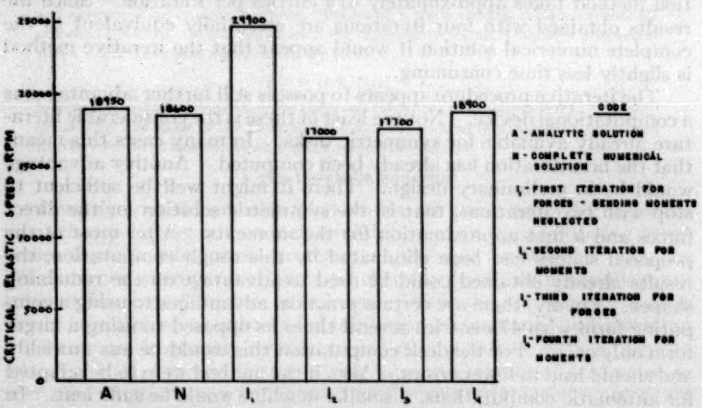

FIG. 15. Comparison of critical elastic speed ω_e obtained by various methods.

First of all, it is evident from Figs. 6 and 7 that with the number of points used the generalization of Manson's method yields a reasonably accurate complete solution. Obviously, the choice of a larger number of points would increase its accuracy. On the other hand, Figs. 12, 13 and 14 show that the iteration method also yields reasonable results after only two complete cycles. In evaluating Figs. 12, 13 and 14 it should be recalled that the iteration solutions were computed numerically using the same points as for the complete numerical solution, so that one could not expect better agreement in Figs. 12, 13 and 14 than in Figs. 6 and 7.

A further basis of comparison may be obtained by computing the maximum elastic speed according to each method. These results are shown in Fig. 15. The analytic, complete numerical, and final iterative solutions are all seen to lie within plus or minus two per cent of each other, hence any of them may be taken as entirely satisfactory. However, as previously noted, the first approximation is equivalent to the complete

neglect of the bending moments and predicts a speed over 30 per cent above the correct value. On the other hand, the first non-zero approximation to the moment distribution yields a result about 10 per cent too low, while the next approximation cuts this error in half.

An obvious factor to be considered in evaluating the numerical methods is the labor involved. The actual calculations were performed on a desk computer, and a rough measure of their relative time consumption is afforded by the number of entries necessary in the machine. For the complete numerical solution this number was found to be approximately equal to $248n$, where n is the number of stations, while the iteration method takes approximately $47n$ entries per iteration. Since the results obtained with four iterations are essentially equivalent to the complete numerical solution it would appear that the iterative method is slightly less time consuming.

The iterative procedure appears to possess still further advantages as a computational device. Not the least of these is the considerable literature already available for symmetric disks. In many cases this means that the first iteration has already been computed. Another advantage would be in preliminary design. There it might well be sufficient to stop with two iterations, that is, the symmetric solution for the direct forces and a first approximation for the moments. After most of the proposed shapes had been eliminated by this rough computation, the results already obtained could be used to advantage on the remaining shapes. Finally, there are certain practical advantages to using a computing form with $47n$ entries several times as opposed to using a larger form only once. For the desk computation this would be less unwieldy and should lead to fewer errors. Also, if the method were to be adapted for automatic computations, a smaller machine would be sufficient. In this latter connection, once the form had already been set up for an automatic computer there would be no particular reason to stop with four iterations—one could just as easily use forty.

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RESEARCHES ON CORROSION AND INHIBITION

ADSORPTION, INHIBITION AND THE LANGMUIR EQUATION

BY

GEORGE S. GARDNER[1]

SUMMARY

Using a previously-described procedure, the author has studied the corrosion velocity of steel in dilute acetic acid, in the presence of an oil phase, and in the presence and absence of an organic inhibitor. Values of s, the fractional surface covered by adsorbed inhibitor, are calculated from the experiments for each inhibitor concentration c. The Langmuir equation, in the form

$$1/s = (1/b)(1/c) + 1,$$

is solved graphically by plotting the observed values of $(1/s)$ against $(1/c)$. It is suggested that the value of the Langmuir constant b, found in this manner, can be used for the over-all evaluation of an organic corrosion inhibitor.

I. THE LANGMUIR EQUATION

Investigators of corrosion phenomena are quite generally in agreement that polar organic corrosion inhibitors exert their inhibiting properties through adsorption processes (1, 2).[2] As to whether van der Waals forces, electrostatic forces, or chemisorption, are controlling, are subjects for some difference of opinion. While the role of adsorption is firmly established as a basis for inhibition phenomena, and corrosion inhibitors are frequently referred to as "strongly adsorbed" or "weakly adsorbed" (3), a means for measuring the actual extent of adsorption in corrosion reactions was not devised until recently (4) when a procedure was described for the determination of the fractional surface area covered by adsorbed inhibitor, and some of these measurements were reported.

The next step in such a study might well be to relate the degree of inhibition to the concentration of inhibitor in the solution. A logical way to do this would seem to be to express the fractional surface covered by adsorbed inhibitor as a mathematical function of the inhibitor concentration. A number of investigators have studied the adsorption of gases and solutes on surfaces, and have given equations to express the relation between the amount of adsorption and the partial pressure of adsorbate in the gas phase, or the concentration of the adsorbate in the liquid phase. Of all these equations, the most useful have been the Freundlich (5) equation and the Langmuir (6) equation. An excellent resumé of these equations is given by Brunauer (7), who believes the Langmuir equation "is perhaps the most important single equation in the field of adsorption."

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[2] The boldface numbers in parentheses refer to the references appended to this paper.

A useful form of the Langmuir equation for adsorption from solution is

$$s = \frac{bc}{1 + bc}, \tag{1}$$

which can be written

$$(1/s) = (1/b)(1/c) + 1. \tag{2}$$

In these equations, s is the fractional surface area covered by adsorbed inhibitor, and c is the concentration of inhibitor, expressed in appropriate units. The constant b will naturally vary according to the units chosen.

II. EVALUATION OF THE LANGMUIR EQUATION

In previously reported research (4), the author and his co-workers have shown that a Nernst equation can be written to express the velocity of diffusion-controlled corrosion reactions. A convenient form of this equation is

$$-(dx/x) = (1 - s)(AD/hV)dt, \tag{3}$$

where

A = area of the corroding metal surface, in cm.^{2},
D = the diffusion coefficient of the reactant in the solution,
h = the thickness of the Nernst "film,"
V = the volume of the solution, cm.^{3},
s = the fraction of the metal surface covered by adsorbed inhibitor,
x = milligrams of reactant in solution at time t,
t = time in hours, measured from the beginning of the experiment.

Integrated, for the condition that $x = x_0$, when $t = 0$, Eq. 3 becomes

$$\ln (x_0/x) = (1 - s)(AD/hV)t, \tag{4}$$

a suitable form for use in graphic solution. If, therefore, we plot t on the abscissa and $\ln (x_0/x)$ on the ordinate, the slope of the curve is the group

$$\frac{(1 - s)(AD)}{hV}. \tag{5}$$

To obtain a value of s from the above equation, it is quite apparent that some way must be found for obtaining a value of AD/hV. This is done by carrying out control experiments in which no inhibitor is used, and s has a value of zero. Since the slope in such experiments is AD/hV, this value can be used in experiments containing inhibitor to obtain $(1 - s)$ and s.

III. EXPERIMENTAL CONDITIONS FOR THE MEASUREMENT OF THE SURFACE COVERED BY ADSORBED INHIBITOR

The experimental procedure for the measurement of the fractional surface covered by adsorbed inhibitor has been described in detail (2). It is sufficient to say here that the corrodent was 30 ml. of a solution containing 40 g./l. of sodium chloride and 1000 ppm. (mg./l.) of acetic acid. The oil phase was 30 ml. of a solution of mineral spirits, thoroughly washed with water. The gas phase was nitrogen, oxygen being thoroughly removed from the vessel and solution. The temperature was 40° C. The metal used in the corrosion velocity measurements was SAE 1010 hot-rolled strip steel, descaled and thoroughly cleaned. The organic inhibitor used in the experiments was Rodine 330, a proprietary corrosion inhibitor of the American Chemical Paint Company. This inhibitor is a nitrogen-base quaternary compound, designed for use in sweet oil wells, water-injection wells, and related applications. The inhibitor is water-soluble and oil-insoluble.

IV. RESULTS OF CORROSION EXPERIMENTS

In Tables I through VII are shown the results of seven series of corrosion experiments. The inhibitor concentrations in these experiments are given in Table VIII.

The time (in hours) refers to the time from the beginning of the particular experiment to the removal of the metal specimen for cleaning and weighing. w(mg.) is the loss in weight of the metal specimen during the experiment. x(mg.) is the amount of reactant (acetic acid, in mg.) remaining in the solution at the end of the particular experiment, and ln (x_0/x) is calculated from the value of x and its original value, x_0.

In Figs. 1 through 7 these results of corrosion experiments are expressed in the form of graphs, where the abscissae are the values of the time and the ordinates are the values of ln (x_0/x). The slopes are calculated, and are, according to Eq. 4, values of $\frac{(1-s)AD}{hV}$.

V. CONFIRMATION OF THE LANGMUIR EQUATION

In Table IX the calculation of s, the fractional surface covered by adsorbed inhibitor, is shown, giving values of $1/c$ and $1/s$ which can be used in the graphical solution of Eq. 2. The plot of $1/c$ *versus* $1/s$ is shown in Fig. 8. Over a wide range of inhibitor concentrations (from 10 to 100 parts per million of inhibitor) the data show excellent agreement with the Langmuir adsorption equation.

VI. THE CONSTANT IN THE LANGMUIR EQUATION

The slope of the curve in Fig. 8 is 5.8, which represents a value for $1/b$ in Eq. 2. The value for the constant b in the Langmuir equation is therefore 0.172.

TABLE I.

t, hr.	w, mg.	x, mg.	ln (x_0/x)
1	1.3	28.7	0.095
1	2.4	26.3	0.182
2	5.2	20.3	0.438
2	5.2	20.3	0.438
2	5.1	20.5	0.425
2	4.0	22.9	0.315
2	4.6	21.6	0.378
2	5.8	19.0	0.507
3	5.2	20.3	0.438
3	5.6	19.5	0.476
4	6.0	18.6	0.531
4	5.6	19.5	0.476
4	8.0	14.3	0.788
4	8.7	12.8	0.900
4	6.3	18.0	0.560
4	5.7	19.2	0.495
5	6.3	18.0	0.560
5	7.6	15.2	0.728
6	6.5	17.5	0.588
6	8.4	13.5	0.846
6	8.7	12.8	0.900
6	7.9	14.5	0.775
6	10.0	10.0	1.147
7	8.9	12.4	0.928
8	9.5	11.1	1.044
8	10.8	8.3	1.332
8	10.6	8.7	1.286
10	10.9	8.0	1.371
10	10.5	8.9	1.264
12	12.1	5.5	1.75
12	12.1	5.5	1.75

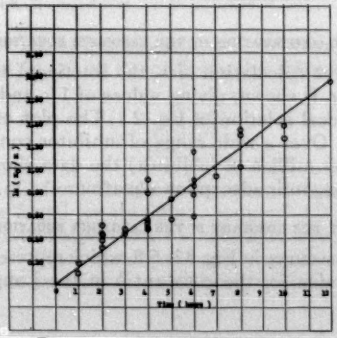

FIG. 1. No inhibitor. Slope, 0.148.

TABLE II.

t, hr.	w, mg.	x, mg.	$\ln (x_0/x)$
2	1.9	27.4	0.140
2	1.7	27.8	0.122
2	3.0	25.1	0.223
4	3.3	24.4	0.255
4	3.4	24.2	0.262
4	5.1	20.5	0.432
6	4.0	22.9	0.315
6	5.6	19.5	0.476
6	5.2	20.3	0.438
8	5.4	19.9	0.458
8	4.4	22.0	0.358
8	6.8	16.9	0.621
10	6.0	18.6	0.525
10	6.8	16.9	0.621
12	6.5	17.5	0.588
12	6.6	17.3	0.599
12	7.6	15.1	0.732
14	8.1	14.0	0.806
14	8.5	13.2	0.867
16	8.8	12.5	0.924
16	7.1	16.2	0.663
16	9.1	11.9	0.971
18	9.1	11.9	0.971

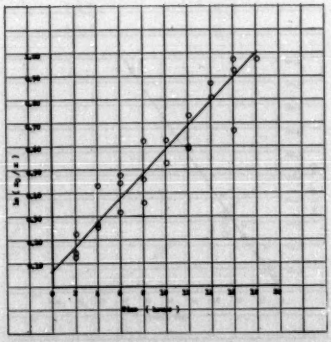

FIG. 2. Inhibitor, 10 ppm. Slope, 0.052.

TABLE III.

t, hr.	w, mg.	x, mg.	ln (x_0/x)
2	1.4	28.5	0.104
2	1.0	29.4	0.068
4	2.6	25.9	0.199
4	2.2	26.8	0.157
6	4.7	21.4	0.385
6	2.8	25.5	0.207
8	3.2	24.6	0.247
8	2.3	26.5	0.174
16	6.4	17.7	0.577
16	5.6	19.5	0.476
24	5.7	19.3	0.489
24	6.9	16.6	0.642
24	8.3	13.7	0.833
24	6.3	18.0	0.560
30	6.1	18.4	0.536
30	4.7	21.4	0.385
30	10.0	10.0	1.147
30	10.6	8.7	1.289
30	10.8	8.2	1.348
40	7.9	14.5	0.775
40	11.1	7.6	1.423
40	11.0	7.9	1.381
40	10.7	8.5	1.308
64	12.5	4.6	1.92

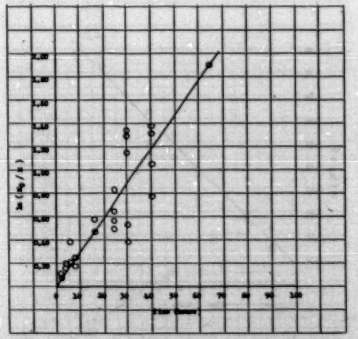

FIG. 3. Inhibitor, 20 ppm. Slope, 0.030.

TABLE IV.

t, hr.	w, mg.	x, mg.	$\ln (x_0/x)$
2	1.3	28.7	0.095
2	2.2	26.8	0.165
2	1.6	28.1	0.113
2	1.2	28.9	0.086
4	3.5	23.9	0.278
4	4.0	22.9	0.315
4	1.5	28.3	0.104
4	1.6	28.1	0.104
6	2.5	26.1	0.191
6	3.7	23.5	0.293
8	2.4	26.3	0.174
8	3.1	24.8	0.239
8	2.8	25.5	0.207
16	3.4	24.2	0.262
16	5.3	20.1	0.445
16	3.4	24.2	0.262
16	2.7	25.7	0.199
20	4.0	22.8	0.322
20	5.3	20.1	0.445
24	4.9	21.0	0.405
24	5.1	20.5	0.425
30	6.1	18.5	0.525
30	5.5	19.7	0.470
40	5.9	18.8	0.513
40	5.3	20.1	0.445
48	6.6	17.3	0.604
48	7.9	14.5	0.775
52	8.0	14.3	0.788
52	8.5	13.2	0.867
79	10.8	8.3	1.34
79	10.5	8.9	1.26

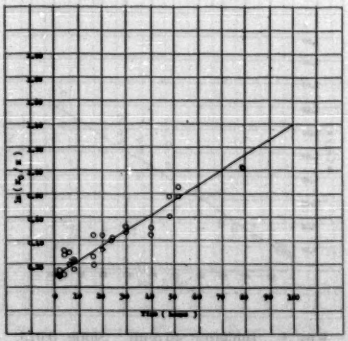

FIG. 4. Inhibitor, 30 ppm. Slope, 0.013.

TABLE V.

t, hr.	w, mg.	x, mg.	ln (x_0/x)
2	2.2	26.8	0.157
2	1.8	27.6	0.131
4	2.1	27.0	0.148
4	2.7	25.7	0.199
6	3.0	25.0	0.231
6	2.2	26.8	0.157
16	4.5	21.8	0.365
16	3.7	23.5	0.293
24	4.2	22.5	0.336
24	4.6	21.6	0.372
30	5.0	20.8	0.412
30	4.6	21.6	0.372
40	5.3	20.1	0.445
40	5.2	20.3	0.438
40	7.5	15.4	0.713
40	7.1	16.2	0.663
48	6.1	18.4	0.536
48	7.3	15.8	0.688
52	8.6	13.0	0.884
52	9.6	10.8	1.068
64	9.3	11.5	1.008
64	9.8	10.4	1.105
64	7.9	14.5	0.775
64	8.1	14.1	0.802
72	9.7	10.6	1.089
72	10.1	9.8	1.169
72	10.7	8.4	1.320
79	9.3	11.5	1.008
96	10.4	9.1	1.24
96	11.5	6.7	1.55

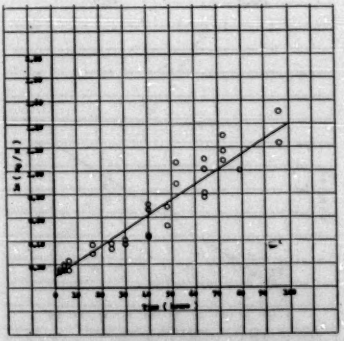

FIG. 5. Inhibitor, 40 ppm. Slope, 0.013.

A study of Table IX and Fig. 8 will show that $1/b$ decreases, or b increases, with the inhibiting strength of the organic inhibitor used. The same information is, of course, obtained from Eq. 1, since a large value of b makes bc large with respect to 1, and causes the value of s, the fractional surface covered, to approach the value 1 more rapidly as the concentration of inhibitor is increased.

TABLE VI.

t, hr.	w, mg.	x, mg.	ln (x_0/x)
2	1.2	28.9	0.086
2	1.6	28.1	0.113
4	2.0	27.2	0.148
4	1.9	27.4	0.140
6	2.2	26.8	0.165
6	1.9	27.4	0.140
12	2.8	25.5	0.215
12	2.4	26.3	0.223
18	2.6	25.9	0.199
18	3.9	23.1	0.307
24	3.6	23.8	0.278
24	3.7	23.6	0.293
36	3.8	23.3	0.300
36	3.2	24.6	0.247
48	4.0	22.9	0.322
48	4.5	21.8	0.372
64	5.0	20.8	0.412
72	6.7	17.1	0.610
72	5.3	20.1	0.451
79	6.2	18.2	0.548
79	7.6	15.2	0.728

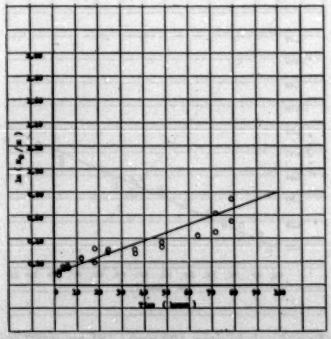

FIG. 6. Inhibitor, 50 ppm. Slope, 0.0070.

TABLE VII.

t, hr.	w, mg.	x, mg.	ln (x_0/x)
4	0.9	29.6	0.058
4	1.1	29.1	0.077
8	1.9	27.4	0.140
8	1.4	28.5	0.095
16	2.4	26.3	0.182
16	1.9	27.4	0.140
24	2.4	26.3	0.182
24	2.9	25.3	0.215
30	3.1	24.8	0.239
30	2.9	25.3	0.215
40	4.0	22.9	0.315
40	3.6	23.8	0.278
52	4.0	22.9	0.315
52	4.3	22.3	0.344
64	4.0	22.9	0.315
64	4.5	21.8	0.365
72	4.3	22.2	0.351
72	4.6	21.6	0.378
79	6.5	17.5	0.588
79	5.2	20.3	0.438
96	5.3	20.1	0.451
96	5.5	19.7	0.470
120	6.3	18.0	0.554
120	6.8	16.9	0.621

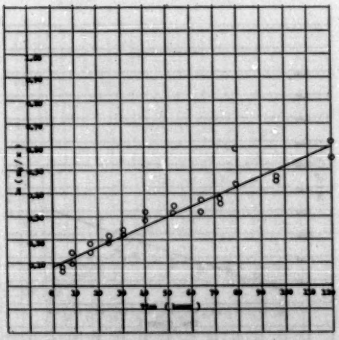

FIG. 7. Inhibitor, 100 ppm. Slope, 0.0043.

It seems that the value of either s or b could be used for evaluating the inhibiting strength of an organic substance. However, while s accomplishes this for one concentration of inhibitor only, b carries the evaluation over a range of concentrations.

TABLE VIII.

Table	Figure	Inhibitor concentration, ppm.
I	1	none
II	2	10
III	3	20
IV	4	30
V	5	40
VI	6	50
VII	7	100

TABLE IX.

c	$\frac{1}{c}$	$\frac{(1-s)AD}{hV}$	$\frac{(1-s)AD}{h}$	$(1-s)$	s	$\frac{1}{s}$
0	—	0.148	4.44	1.0	0	—
10	0.10	0.052	1.56	0.352	0.648	1.54
20	0.05	0.030	0.90	0.203	0.797	1.26
30	0.033	0.013	0.39	0.0879	0.912	1.10
40	0.025	0.013	0.39	0.0879	0.912	1.10
50	0.020	0.0070	0.21	0.0473	0.953	1.05
100	0.010	0.0043	0.129	0.0291	0.971	1.03

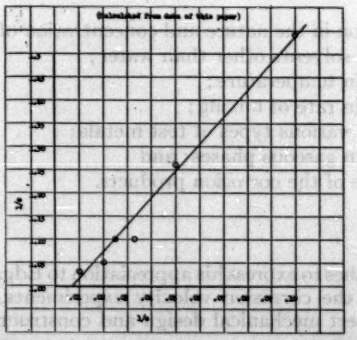

FIG. 8. Confirmation of the Langmuir equation for inhibitor adsorption.

VII. DISCUSSION OF RESULTS

Anyone who has made corrosion experiments such as described in this paper will recognize the fact that they are essentially semi-micro experiments, and susceptible to some variation. In order to obtain a satisfactory degree of agreement the following procedure has been observed:

(*a*) Extreme care has been used in setting up the conditions for the experiments and in carrying them out.
(*b*) The best possible uniformity has been obtained in experimental materials, including the metal test specimens.
(*c*) Multiple experiments have been carried out at each time point, to obtain a statistical average.

In the plots of the seven experiments, in Figs. 1 through 7, the best line has been drawn through the various sets of points. The distribution of experimental points obtained is considered to represent a satisfactory distribution for the determination of the slope in each experiment, and for the later confirmation of the Langmuir equation.

While this investigation has covered one set of experimental conditions only, the object has been to point out and exemplify a method of study which might be employed profitably in the study of various corrosion reactions, in which inhibition by adsorbed organic compounds is important. Many variations in materials and procedure suggest themselves, most of which are the subject of study in this laboratory. Among these variations can be mentioned:

(*a*) Different types of inhibitors;
(*b*) Studies with and without oil phases, and variation in the type of oil phase;
(*c*) Modification in the nature and concentration of the corrodent;
(*d*) The use of solvents other than water;
(*e*) Variation in temperature;
(*f*) Variation in rate of mixing;
(*g*) The use of various types of test metals;
(*h*) Variation in gaseous phases; and
(*i*) The nature of the corrosion products.

Acknowledgments

The writer wishes to express his appreciation to Edgar S. Hayman, Jr., who carried out the corrosion velocity experiments, and to John E. Waldrum for expert mechanical design and construction.

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Future Computers.—Two scientists looked into the future design of large-scale computing machines; one saw the vacuum tube as made obsolete for computers now being designed by the newer transistors and magnetic amplifiers. The other, looking even further into the future, foresaw the eventual decline of the transistor in favor of new ferromagnetic films, which will carry the speed of switching to as little as one billionth of a second.

Their forecasts were given at the International Symposium on the Theory of Switching at Harvard University.

The first, Dr. Theodore H. Bonn of the Remington Rand Division of Sperry Rand, speaking of computers to be built in the immediate future, said "After 13 years of prominence, the vacuum tube is burned out as a computer component. One might well ask how long the transistor and magnetic amplifier will remain on the scene.

"Because of recent improvements in the reliability of transistors it is safe to say that most of the computers under development in the laboratory now will make use of solid-state pulse amplifiers and switches (such as transistors) rather than thermionic devices (i.e., vacuum tubes)."

The second speaker, Dr. Herbert Callen, discussed components which will fulfill the needs of computers not yet even on the drawing board, and showed how scientists are approaching the theoretical upper limits of computation speed. Dr. Callen, who is a professor of physics at the University of Pennsylvania, suggested to an audience of more than eight hundred scientists that a replacement superior to the transistor will be needed for future high speed calculators.

"Within the few short years of computer development, fantastic increases of computer speed have been achieved. The eventual limit beyond which nature will forbid further advance is already in sight. This limit is set by the relativistic law that no physical signal can propagate with a velocity in excess of the velocity of light. The speed of calculation is therefore limited by the times required to transfer information from point to point within the machine. A characteristic distance is perhaps ten centimeters, corresponding to a time of one third of a millimicrosecond. (One-third of one billionth of a second). Computing times in the millimicrosecond range are only two or three orders of magnitude faster than presently planned machines, and are already the topic of at least tentative exploration.

"As each increase in computing speed has occurred, it has been accompanied by the development of a new basic component. The mechanical relay yielded to the vacuum tube, and that in turn has been supplanted by the solid state devices such as magnetic cores and transistors. The thin ferromagnetic film is a new component in the latter class, and it is one of the few components which may be expected to perform successfully at one millimicrosecond switching speeds."

While the ability of computers to operate at high speeds is influenced by other factors than the ability of switches to respond quickly, the new ferromagnetic film switches should further increase the speeds of computers, which already can provide answers faster than scientists can ask questions.

SHEAR BUCKLING OF SIMPLY SUPPORTED RECTANGULAR PLATES TAPERED IN THICKNESS

BY

BERTRAM KLEIN [1]

SUMMARY

Design curves are presented for determining the elastic buckling loads of a class of simply supported rectangular plates linearly tapered in thickness in one direction and loaded in pure shear. The problem is solved by a simple straightforward numerical method involving a very small matrix.

INTRODUCTION

With the increasing use of rolled, machined, or chem-milled skins in aircraft and missile designs, analyses of plates tapered in thickness are becoming the rule rather than the exception. Design data for the buckling of such plates are limited. The author has presented solutions for compressive buckling of tapered plates (1).[2] It is the purpose of the present paper to present data for shear buckling of certain tapered plates. For purposes of simplicity, the taper is assumed to be linear and only in one direction as shown in Fig. 1. In addition, the plate material

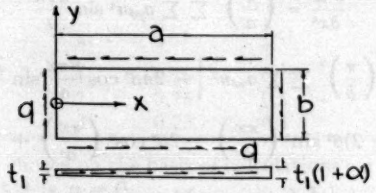

FIG. 1. Tapered plate geometry and loading.

is assumed to remain elastic under load, which is assumed to be a constant shear flow.

NOTATION

a, plate length
a_{mn}, deflected shape coefficient
b, plate width
D, plate flexural rigidity
D_1, plate flexural rigidity at $x = 0$
E, Young's modulus
k, buckling coefficient
m, $1,2,3,\cdots$
q, shear flow
t, plate thickness
t_1, plate thickness at $x = 0$
w, plate normal deflection
x,y, rectangular coordinates
α, thickness taper parameter
β, deflected shape parameter
Δ, $\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}$
ν, Poisson's ratio $= 0.3$
ϕ, see Eq. 1

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[2] The boldface numbers in parentheses refer to the references appended to this paper.

METHOD OF SOLUTION

The problem is solved by the method of collocation (1, 2). The buckling mode of the plate is assumed in the form:

$$w = \sum_{n=1} \sum_{\beta} a_{n\beta} \sin\left(\frac{n\pi x}{a} - n\beta \sin\frac{\pi y}{b} \sin\frac{\pi x}{a}\right) \times \cos\frac{\pi y}{b} = \sum\sum a_{n\beta} \sin\phi \cos\frac{\pi y}{b}. \quad (1)$$

It can be shown that this function satisfies all the simply supported boundary conditions at all boundary points.

Points for collocation are taken along the x axis, that is, $y = 0$. The following are partial derivatives of w at $y = 0$ computed from formulae similar to those listed in the appendix of (3).

$$\frac{\partial^2 w}{\partial x \partial y} = \left(\frac{\pi}{a}\right)\left(\frac{\pi}{b}\right) \sum\sum a_{n\beta}\beta \times \left(n^2 \sin\frac{n\pi x}{a} \sin\frac{\pi x}{a} - n \cos\frac{n\pi x}{a} \cos\frac{\pi x}{a}\right) \quad (2)$$

$$\frac{\partial^4 w}{\partial x^4} = \left(\frac{\pi}{a}\right)^4 \sum\sum a_{n\beta} n^4 \sin\frac{n\pi x}{a} \quad (3)$$

$$\frac{\partial^4 w}{\partial x^2 \partial y^2} = \left(\frac{\pi}{a}\right)^2 \left(\frac{\pi}{b}\right)^2 \sum\sum a_{n\beta} n^2 \left\{ -2n\beta^2 \cos\frac{n\pi x}{a} \sin\frac{2\pi x}{a} + \left[(n^2+2)\beta^2 \sin^2\left(\frac{\pi x}{a}\right) - 2\beta^2 \cos^2\left(\frac{\pi x}{a}\right) + 1\right] \sin\frac{n\pi x}{a} \right\} \quad (4)$$

$$\frac{\partial^4 w}{\partial y^4} = \left(\frac{\pi}{b}\right)^4 \sum\sum a_{n\beta} \left[\left(n\beta \sin\frac{\pi x}{a}\right)^4 + 10\left(n\beta \sin\frac{\pi x}{a}\right)^2 + 1\right] \sin\frac{n\pi x}{a} \quad (5)$$

$$\frac{\partial \Delta w}{\partial x} = -\left(\frac{\pi}{b}\right)^2 \left(\frac{\pi}{a}\right) \sum\sum a_{n\beta} \left\{ \left[n^3\beta^2 \sin^2\frac{\pi x}{a} + n^3\left(\frac{b}{a}\right)^2 + n\right] \cos\frac{n\pi x}{a} + n^2\beta^2 \sin\left(\frac{2\pi x}{a}\right) \sin\frac{n\pi x}{a} \right\} \quad (6)$$

$$\frac{\partial^2 w}{\partial x^2} + \nu\frac{\partial^2 w}{\partial y^2} = -\left(\frac{\pi}{b}\right)^2 \sum\sum a_{n\beta} \times \left\{ \left(\frac{nb}{a}\right)^2 + \nu\left[n^2\beta^2 \sin^2\left(\frac{\pi x}{a}\right) + 1\right] \sin\frac{n\pi x}{a} \right\}. \quad (7)$$

The differential equation in the present problem is:

$$D\Delta\Delta w + 2\frac{dD}{dx}\frac{\partial \Delta w}{\partial x} + \frac{d^2D}{dx^2}\left(\frac{\partial^2 w}{\partial x^2} + \nu\frac{\partial^2 w}{\partial y^2}\right) - 2q\frac{\partial^2 w}{\partial x \partial y} = 0, \quad (8)$$

where for the type of plate thickness taper considered,

$$D = D_1\left(1 + \alpha\frac{x}{a}\right)^3. \quad (9)$$

The particular plates considered have aspect ratios and thickness tapers as follows:

$$\frac{b}{a} = 1, 0.5, 0.33; \quad \alpha = 0.5, 1, 2. \quad (10)$$

Three points are taken for collocation as

$$\frac{x}{a} = 0.2, 0.3, 0.4 \quad (11)$$

which lie in the region of maximum plate deflection for the aspect ratios considered. The three values of β are taken as follows:

n	$\frac{b}{a}=1$	$\frac{b}{a}<1$
1	0.75	0.75
2	0.75	0.5
3	0.75	0.4

(12)

These values are chosen on the basis of calculations carried out for non-tapered plates, that is, $\alpha = 0$.

Upon evaluation of Eqs. 2–7 at the above points and substitution of the results into Eq. 8, a three by three matrix results. The form is a standard eigenvalue one. Solution of the characteristic equation yields three roots for buckling. Examination of these roots reveals the buckling load.

RESULTS

Results of the calculations are shown in Figs. 2 and 3 in terms of the buckling coefficient

$$k = \left(\frac{b}{\pi}\right)^2\frac{q}{D_1} \quad (13)$$

so that the buckling load is

$$q = \frac{kE\pi^2 t_1^3}{12(1-\nu^2)b^2}. \quad (14)$$

The curves for $b/a < 0.33$ in Fig. 3 are obtained by cross plotting the curves in Fig. 2.

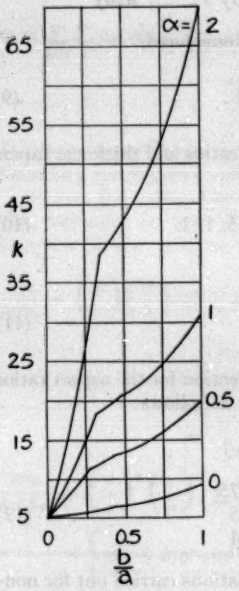

FIG. 2. Shear buckling coefficient *versus* aspect ratio for given thickness tapers.

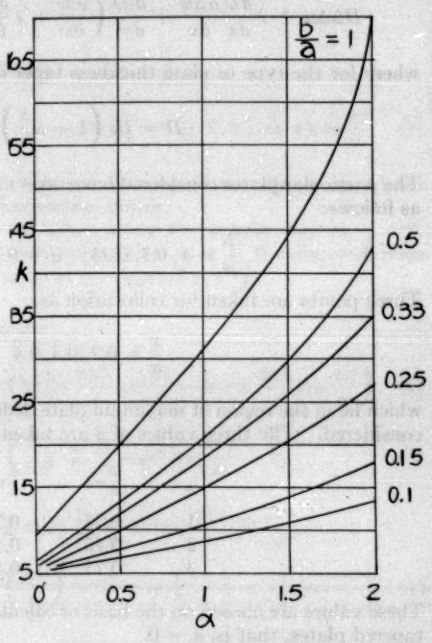

FIG. 3. Shear buckling coefficient *versus* thickness taper for given aspect ratios.

SECONDARY BOUNDARY CONDITION

Subsequent to completion of the work, it was found that a simple additional equation in $a_{n\beta}$ is obtained by collocating on the boundary at $x = 0$. In the present instance, this equation is:

$$-\frac{3}{\pi}\left(\frac{b}{a}\right)\alpha \sum\sum a_{n\beta}\left[n^3\left(\frac{b}{a}\right)^2 + n\right] + k \sum\sum a_{n\beta} n = 0 \qquad (15)$$

and may be looked upon as a secondary boundary condition which should be satisfied. In order to satisfy this equation, the matrix should be expanded to a four by four. In future work it will be of advantage to include such equation.

CONCLUSIONS

It should be apparent that the present method may be used to solve cases where t varies in a manner other than linear, and/or q is not constant. Equation 8 still holds, and the expression given for w in Eq. 1 is general.

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(1) B. KLEIN, "Compressive Buckling under Varying Loading of Simply Supported Plates Simultaneously Tapered in Planform and in Thickness," *Aircraft Engineering*, Vol. 28, p. 1427 (1956).

(2) R. A. FRAZER, W. P. JONES AND S. W. SKAN, "Approximations to Functions and to the Solution of Linear Differential Equations," British R&M No. 1799, 1937.

(3) B. KLEIN, "Buckling of Simply Supported Plates Tapered in Planform," *J. Appl. Mech.*, Vol. 23, pp. 207–213 (1956).

Tornado-Proof Houses.—For only a few hundred dollars extra, features can be built into houses and business establishments which will make them virtually "tornado-proof," a University of Michigan meteorologist believes. This is the conclusion of George W. Reynolds, research associate in the Engineering Research Institute, who has closely studied the destructive storms since 1949.

After touring the scenes of nine tornadoes and reading technical reports on hundreds of them, Reynolds is convinced houses can be built to survive most, if not all, such storms. The increase in cost would range from $50 to $350, he estimates, and properly built structures might eliminate as much as 90 per cent of tornado deaths and injuries, he says.

Reynolds has found that the great majority of structures destroyed in tornadoes suffered from one or more of three major shortcomings: improper anchorage, insufficient internal bracing, or lack of proper air vents. Improper anchorage of a house to its foundation, or of a roof to the building, can result in its being tipped over or the roof being peeled off, Reynolds notes.

"In my personal investigation of tornadoes, I have yet to see a single case in which a house bolted to its foundation was destroyed. This is not conclusive proof, of course, but it is certainly suggestive."

The "suction" from fast-moving winds in the lee of a building and the change in atmospheric pressure during a tornado also can cause poorly braced walls to fall outward, Reynold says.

"All the wind has to do is pull a few nails, and the wall is gone, just as you knock the sides off a box," he points out. Reynolds suggests inexpensive ties to hold each wall securely to its neighbors.

At the same time, simple vents in attics and basements could equalize the pressure inside and outside a house, he says.

"More research is needed before anyone can say for sure, but it looks like an air escape area on the order of one or two feet square for each 1000 feet of floor space might be enough to keep houses from exploding during all but the worst part of the most severe tornadoes."

Reynolds reported on this aspect of the subject at the national meeting of the American Meteorological Society at the University of Chicago.

His studies have led him to doubt that tornado winds are as strong, or the drop in air pressure as great, as popularly thought.

Although maximum wind speeds in a few tornadoes may reach 300 miles an hour, Reynolds suspects the maximum speeds in most tornadoes are between 100 and 200 miles an hour. Then, too, Reynolds notes, there is no great "vacuum" in the center of a tornado. The pressure on the inside of most tornadoes appears to be about 75 per cent of the pressure on the outside and is probably closer to 90 to 95 per cent," he said.

NOTES FROM THE NATIONAL BUREAU OF STANDARDS

PORTABLE FREQUENCY STANDARD

A small, compact frequency standard that requires only periodic connection to a commercial power line has been developed at the Boulder Laboratories of the National Bureau of Standards. The standard was devised by A. H. Morgan of the NBS Radio Standards Laboratory under the sponsorship of the U. S. Army Signal Corps.

Adapted for use in this unit is the principle of the latent-heat stabilization method for controlling enclosed-space temperature, developed by Robert Alvarez of the NBS Chemistry Division.[1] Using diphenyl at its double-point (about 70° C.) that is, at a temperature where it exists as a mixture of solid and liquid, a temperature stability of a few hundredths of a degree centigrade was obtained. The oscillator stability was ± 1 part in 10^7 over a period of several hours.

The instrument is expected to prove valuable for airborne use and in other cases where a stable but portable frequency source is required. Until now, all frequency standards of this precision have been large and bulky and have required continuous connection to a commercial power line.

The apparatus consists of a transistor crystal-controlled oscillator and a two stage transistor buffer-amplifier which are operated continuously from four small mercury cells contained in the bottom compartment of the standard. All components of the circuit are enclosed in the diphenyl oven which maintains them at a constant temperature.

Surrounding the diphenyl is an electric heating coil controlled by a microswitch. When the diphenyl is heated it increases in volume and presses against the bottom of bellows located in the inner compartment. This movement of the bellows closes the microswitch and opens the heater circuit. The heater can be adjusted to operate at varying degrees of temperature by a shaft which controls the height of the upper contact point of the microswitch. Heat losses from the oven are reduced by a heat radiation shield and a vacuum insulation space.

After the oven temperature has been stabilized at the double-point temperature of the diphenyl, the unit may be disconnected from the power source which supplied the initial heat, and operated for several hours on temperature without external power connections.

[1] "Constant-Temperature Oven for Quartz Crystal Oscillator," *NBS Tech. News Bull.*, Vol. 40, p. 59 (1956).

External controls are provided on the developmental model to adjust the oscillator frequency (coarse and fine frequency controls); the oscillator tank capacitor for best output voltage; and the oven temperature. An inexpensive, commercial, one-megacycle quartz crystal is used to control the frequency of the oscillator. The output voltage is about 400 millivolts into a 600-ohm load.

Silicon junction transistors were chosen for the oscillator and amplifier because of their ability to operate at high temperatures (up to 150° C.), whereas germanium transistors cease operation around 80° C. The over-all efficiency of the oscillator and amplifier is around 78 per cent (input power from mercury cells is 7 milliwatts and matched load output power is 5.4 milliwatts).

FATIGUE TESTING MACHINE FOR SPRING WIRE

A recently constructed machine for fatigue-testing small diameter wire is proving very useful in studies of spring materials at the National Bureau of Standards. Developed by J. A. Bennett and H. C. Burnett of the Bureau's mechanical metallurgy laboratory, the machine stresses the straight wire sample in reversed torsion, simulating the stresses in a coiled spring under fluctuating tension or compression load. Results obtained with straight wire in this way show good correlation with the results of fatigue tests on compression springs coiled from similar wire.

Because helical springs are often used in applications where they are subjected to many cycles of fluctuating load, their fatigue properties are of major importance. To provide data in this area, the Army Ordnance Corps has for several years sponsored a study of the fatigue properties of spring materials at the Bureau. However, fatigue tests on compression springs are time consuming, and special care is required in coiling, grinding, and measuring the spring before test. The present machine was designed to determine the torsional fatigue properties of spring wire without need of coiling wire into springs. Set-up time is thus greatly reduced as the ends of the straight-wire specimens need only be bent at right angles.

The machine consists essentially of two aligned grip heads that hold the wire specimen while they oscillate individually through an angle of about 120 deg. The amplitude of deflection in the specimen is set by means of an adjustable coupling that shifts the phase relation between the oscillating grips.

The torsional strain for various settings of the adjustable coupling is determined by means of a clip-on dial-and-pointer combination. The dial and pointer are clipped onto the test wire with a predetermined separation (usually 1 in.). Thus, when the two heads rotate relative to each other, the pointer gives a dial reading of twist per unit length of test specimen.

A rubber coupling in series with one of the grip heads provides a small amount of tension on the specimen. When the specimen fails, the rubber coupling retracts the head and thus opens a switch that stops the machine. The number of oscillations at failure is then given by a counter which is driven through a reducing gear assembly attached directly to the motor shaft.

Power is provided by a 1/20-horsepower electric motor. The motor causes rotation of a horizontal shaft which is connected at one end to a second horizontal shaft by the adjustable coupling previously mentioned. The free ends of the two horizontal shafts are connected to the shafts of the grip heads by crank mechanisms in such a way as to cause oscillatory motion of the grip heads. Thus, by adjusting the coupling, the relative motion of the two heads can be controlled.

THE FRANKLIN INSTITUTE

MINUTES OF THE STATED MEETING

May 15, 1957

The Stated Monthly Meeting of The Franklin Institute was held on May 15, 1957, in the Lecture Hall. Mr. S. Wyman Rolph, President, called the meeting to order at 8:15 P.M. with approximately 200 members and guests in attendance.

The President stated that the minutes of the Stated Meeting of March 20, 1957, were printed in the April JOURNAL and that if there were no corrections or additions they would stand approved as submitted. The minutes of the Stated Meeting of April 17, 1957, will be printed in the May issue of the JOURNAL.

Mr. Rolph announced the retirement of Dr. James Barnes at the end of this month and asked the Secretary to read a Resolution of the Board of Managers adopted at their meeting held this afternoon. The Secretary then read the Resolution:

RESOLVED, that on the occasion of the retirement of James Barnes, the Board of Managers expresses its appreciation for the many years of service that Dr. Barnes has rendered to The Franklin Institute. He became a member of The Franklin Institute in October 1912 and a member of the Committee on Science and the Arts the following year. He was a member of the Board of Managers from 1925 to 1931. He became a member of the staff in 1930 as Director of the Physics Section of the Museum that was being planned for the new building. Since then he has continued to serve in a number of important positions, the most recent having been in connection with Friends of Franklin and as Director of Meetings.

Mr. Rolph then announced that in order not to interfere with the scientific meeting planned, the important item of business, namely, the consideration of the proposed revision of the By-Laws of The Franklin Institute by the voting members, would be postponed until after the lecture. Hearing no objection, Mr. Rolph proceeded with the program which was arranged as The Franklin Institute's contribution to the world-wide celebration of the Centenary of the Birth of Nikola Tesla.

The President then introduced Dr. Carl Chambers, Vice President for Engineering at the University of Pennsylvania, who told about the Nikola Tesla Celebration which he attended in July 1956 in Belgrade, Yugoslavia.

Mr. Rolph next introduced Mr. Kenneth Swezey, a close personal friend of the late Nikola Tesla. Mr. Swezey described a book published by the Nikola Tesla Museum titled "Nikola Tesla 1856–1943—Letters, Patents and Articles," a copy of which he presented to The Franklin Institute. Mr. Rolph acknowledged this gift with thanks. Mr. Rolph then presented Mr. Swezey with an embossed copy of a Resolution adopted by the Board of Managers of The Franklin Institute congratulating the Nikola Tesla Museum for its admirable work in the perpetuation of the memory of Nikola Tesla, with the request that he forward it to the Nikola Tesla Museum in Belgrade.

Mr. Rolph then presented the speaker of the evening, Dr. Samuel G. Hibben, Engineering Consultant in Radiation and Illumination. Dr. Hibben spoke on "From Tesla Until Tomorrow—The Magic of Making Light." In his introductory remarks Dr. Hibben gave an interesting biographical sketch of Nikola Tesla and spoke of the inspiration that his work has given to the world of science and engineering. Dr. Hibben spoke of the progress of illumination in the past fifty years, gave striking demonstrations of the improvements made in the science of lighting, and demonstrated types of lighting that are now in the development stage. Many of these developments and those to come he credited as the result of the "dreams" and work of Nikola Tesla. At the conclusion of his lecture-demonstration, the audience gave Dr. Hibben a rising vote of thanks for his very inspiring talk.

Mr. Rolph then asked the voting members of the Institute to remain for the business meeting. He called the meeting to order and referred to a notice of April 30, 1957, to the voting members of The Franklin Institute proposing an extensive revision of the By-Laws of The Franklin Institute. The Chairman then called for a motion on the proposed revision

of the By-Laws. Mr. Richard T. Nalle presented the following Resolution and moved its adoption:

RESOLVED, that the By-Laws of The Franklin Institute of the State of Pennsylvania for the Promotion of the Mechanic Arts be amended in their entirety to read as set forth as a part of the notice to members dated April 30, 1957, and the effective date of the amended By-Laws shall be July 1, 1957.

Mr. W. Laurence LePage seconded the motion. Mr. Rolph called for discussion. There was none. The motion was unanimously adopted.

Meeting adjourned 10:15 P.M.

WILLIAM F. JACKSON, JR.
Secretary

ED. NOTE: The new By-Laws will be published in this JOURNAL for September, 1957.

COMMITTEE ON SCIENCE AND THE ARTS

(Abstract of Proceedings of Stated Meeting held Wednesday, May 8, 1957.)

HALL OF THE COMMITTEE,
PHILADELPHIA, MAY 8, 1957.

MR. JOHN H. NEHER in the Chair.

The following report was presented for final action:

No. 3321: Levy Medal.

This report recommended the award of the Louis E. Levy Medal to David Barnard Steinman, of New York, New York, "In recognition of his outstanding paper, 'The Design of the Mackinac Bridge for Aerodynamic Stability,' appearing in the December, 1956 issue of the JOURNAL OF THE FRANKLIN INSTITUTE."

D. S. FAHRNEY,
Secretary to Committee

MEMBERSHIP

ACTIVE MEMBERS ELECTED BY THE BOARD OF MANAGERS

May 15, 1957

ACTIVE FAMILY

Edward T. Crossan
Thomas S. Dix, Jr.
Charles D. Johnson
Semond Levitt
Ernest Scott
Harry J. Tiedeck
John B. Yerkes

ACTIVE

Oliver S. Aikman
John T. Aldrich, Jr.
Joseph G. Althouse
Frank R. Amand
Alfred M. P. Amey
Dallas R. Andrews
Harold T. Baldwin
Joseph J. Benischeck
Allen C. Bradham
Frederick N. Beegle, II
William T. Carter
Samuel A. Crozer
Charles R. Fox
John S. Harp
Edward Hungerford
Madeleine N. Joullie
J. Wesley Leas
D. Richard Levy
T. Grier Miller
David R. Powers
Walter L. Schultze
Ronald Souser
J. H. Stoner
William H. Taylor
Brinton J. Wilson
William G. Wood
Yusuf A. Yoler

ACTIVE NON-RESIDENT

William D. McCuin

NECROLOGY

Mrs. Edgar W. Baird '50
Harold N. Brown '44
Walter Chism '52
P. F. Coleman '36
William S. Doughten '36
Arthur E. Jones '47
John B. Lownes '42
Walter C. Mabie '51
Bernhardt Mosler '50
Charles J. Reimer '51

LIBRARY

The Committee on Library desires to add to the collections any technical works that members may wish to contribute. Contributions will be gratefully acknowledged and placed in the Library. Duplicates received will be transferred to other libraries as gifts of the donor. 554 items have been added the past month.

Photostat service. Photostat prints of any material in the collections can be supplied on request.

The Library and reading room are open from 9 A.M. until 5 P.M. on Mondays, Tuesdays, Thursdays, Fridays; from 2 P.M. until 10 P.M. on Wednesdays; and from 9 A.M. until noon on Saturdays.

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NOTES FROM THE FRANKLIN INSTITUTE MUSEUM

A. C. CARLTON, DIRECTOR

STEEL

In 1782, Samuel Highley of Rhode Island manufactured what is believed to have been the first piece of steel made in the American colonies. He had probably learned the technique of the process from a book written in 1720 by the French physicist Reaumur. Steel made by this process was called "blister" steel because the bars were covered with blisters when withdrawn from the furnace.

The process was carried on in a steel furnace, where iron bars were laid in the hearth, sprinkled with charcoal dust, horn shavings, and ashes. To this a blast was applied which continued until test bars revealed what the operator believed was the right color. Then the fire was extinguished and the bars were left to cool. The Pennsylvania Germans had a different method of making steel. In their process, pig iron or crude iron was used instead of bar iron, and special woods were employed for fuel. This particular technique was called "after the German manner."

At the outbreak of the Revolution, the Provincial Congress of Pennsylvania urged its people to manufacture steel, iron, wire, and tin plate, although they can have had no conception of the extent to which the industry would grow within their province. At the eve of the Civil War, the modern steel industry began to take shape. The Kelly-Bessemer process, refinements and improvements in the blast furnace, the opening of the Lake Superior iron ore region, the introduction of coke in place of wood fuel, all combined to bring about the rapid expansion of the industry. The development of the railroads made the distribution of coal and coke nationwide. The basis for the mighty industry had been laid and production began to soar.

New machines, new techniques, and efficient management all combined to promote the United States into the position of leadership in the world's steel industry. But the contributions of the chemist and metallurgist should not be overlooked for, essentially, iron and steel making is a chemical process on a very large scale in which the furnaces and converters are giant test-tubes where the ingredients, according to prescribed formula are transformed by chemical changes. The skilled artisan who had dominated the process was replaced by the worker in the research laboratory, although the man of brawn and muscle still tosses heavy ingots with his tongs as through they were toys. The American steel-worker takes a justifiable pride in his achievements. He

even has his mythical hero—Joe Magarac—whose exploits rival those of Paul Bunyan.

Rails to meet the expansion of the railroads gave the industry its first impulse. This was followed by the demand for wire nails, and soon after that the demand of farmers for wire fencing proved to be a third impulse to send the industry upon its way to supremacy. Today, steel enters into the production of innumerable things, from great battleships to surgeon's needles. It would be very difficult to think of anything in a daily life that does not contain steel or is not dependent upon steel for its production: For the United States is not only the world's largest producer of steel, it is also the largest consumer.

The significance of the steel industry in national history is not to be measured by the production of materials made from iron and steel, but rather by the impact of steel on all phases of American life. History is affected as much by technology as it is by the rise and fall of dynasties.

In order to appreciate the deep penetration of the steel industry into the life of the nation as well as that of the individuals who compose the nation, Museum visitors can obtain a comprehensive picture from the story presented by Bethlehem Steel Company in their exhibit. Unimpeded by unnecessary information and shorn of all technical terms the story is told in a manner that makes it impressive with the minimum of mental effort on the visitor's part. It will be found on the First Floor.

BARTOL RESEARCH FOUNDATION
W. F. G. SWANN, DIRECTOR

SEARCH FOR A LONG-LIVED RADIOISOTOPE OF NEODYMIUM*

BY

V. S. DUBEY,[1] V. R. POTNIS,[2] C. E. MANDEVILLE, AND W. B. KEIGHTON[3]

ABSTRACT

Neutron irradiated neodymium has been examined for the possible presence of long-lived activities in the rare earth region of undetermined elemental and isotopic assignment. No such long period radioelements were detectable. Scintillation counting methods and ion exchange columns were employed to show that a composite contribution from three isotopes of europium may have been misinterpreted as evidence for the presence of a 1.7-yr. activity of neodymium. These elements are formed by neutron capture in europium and samarium present as impurities in neodymium.

When neodymium is irradiated by slow neutrons, radioactive elements are formed with half-periods of 12 min., 2.3 hr., 27.5 hr., 50 hr., 11 days, and 2.5 yr. In order of increasing lifetime, the isotopic assignments are Nd^{151}, Nd^{149}, Pm^{151}, Pm^{149}, Nd^{147}, and Pm^{147}. In addition, a long period activity ($T_{1/2} \sim 1.7$ yr.) has been noted (1),[4] having associated with it a beta-ray spectrum of maximum energy 0.74 Mev (1). This radioelement was considered to be an isotope of neodymium (1).

In the course of other investigations (2), successive samples of very pure (3) Nd_2O_3 were five times irradiated in the Brookhaven reactor. After an appreciable time of decay, it became apparent that a long period activity had been induced in all five quantities of target material. The beta and gamma-ray emissions of this long period element were separately followed for more than one year, and were estimated to decay with an approximate lifetime of 1.7 yr. When measured in an anthracene scintillation counter, the bulk of the beta rays were found to have a maximum energy of ~230 kev and were furthermore observed to be non-coincident with gamma radiation. From these measured characteristics, it could be concluded that this soft beta spectrum was that of the 2.5-yr. promethium (Pm^{147}) which is grown from the 11-day Nd^{147}. The gamma rays were of sufficient intensity that their energies were readily measurable in a sodium iodide (thallium activated) scintillation counter. Their quantum energies were found to be 84, 102, 120, 240, 340, 780, 960, 1100, and 1380 kev. The three soft

* Assisted by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.

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[2] Permanent Address, Gwalior (M.P.), India.

[3] Department of Chemistry, Swarthmore College, Swarthmore, Pa.

[4] The boldface numbers in parentheses refer to the references appended to this article.

gamma rays at 84, 102, and 120 kev were actually resolved only when coincidence measurements were performed, employing two scintillation spectrometers. The 120-kev gamma ray was found to be coincident with gamma rays of higher energy, whereas the 84- and 100-kev gamma rays were non-coincident with other quantum radiations.

The ~1.7-yr. activity was also noted to be emitting intense X-radiation of an energy approximately that of the K-line of the neodymium region. The X-radiation was observed to be coincident with the 120-kev gamma ray and the gamma rays of higher energies. No coincidences were observable between the X-rays and the gamma rays at 84 and 100 kev. Critical absorption measurements were carried out using absorbing media of I, Cs, Ba, La, and Ce, and it was concluded that the X-rays were characteristic of the element neodymium. Thus, the results might have been interpreted as evidence for the existence of a long-lived K-capture activity in promethium.

Simultaneously with the experiments on neodymium, samples of naturally occurring samarium as well as targets enriched in Sm^{144} were also irradiated at the Brookhaven reactor. In all irradiated quantities of samarium, the long-lived gamma-ray emitter of the neodymium experiments was also detected. It was always present with an intensity which allowed measurement of the entire gamma-ray spectrum. This result did not contradict the view that the long-lived activity might be assignable to promethium, because it could have been formed by an (n,p)-reaction in the reactor, brought about by the action of fast neutrons.

The sequence of events recorded above suggested that elemental separations should be carried out with the application of ion exchange columns. Accordingly, several columns were erected. These columns were packed with the ammonium form of Dowex-50, a cation exchange resin. Oxides of the rare earths were dissolved in concentrated hydrochloric acid, diluted to 0.3 *N*—HCl concentration, and introduced into the top of columns 100 cm. in length and 1.1 to 1.2 cm. in internal diameter. The rare earths were eluted at room temperature with a 5-per cent citric acid solution which had been brought to a pH value of 3.2 by addition of ammonia. The rate of elution was about 20 ml. per hour. When the irradiated neodymium was passed through a column, "cuts" containing promethium could be identified by the presence of the beta rays of Pm^{147}. When radioactive samarium was placed in a column, "cuts" containing samarium could be identified by the presence of the long-lived Sm^{145} K-capture activity. Thus, fractions containing promethium and samarium were "tagged." In all instances, the gamma ray emitting long-lived activity was found to precede promethium and samarium in passing through the columns. From the known behavior of ion exchange columns, it could be concluded from these observations that the ions having the gamma-ray activity must carry a nuclear

charge greater than those of promethium and samarium. That the gamma-ray activity of the unknown radioelement preceded the beta activity of Pm^{147} through the column is illustrated in Fig. 1. Each "cut" was 100 cc. in volume. In observing the gamma-ray activity the

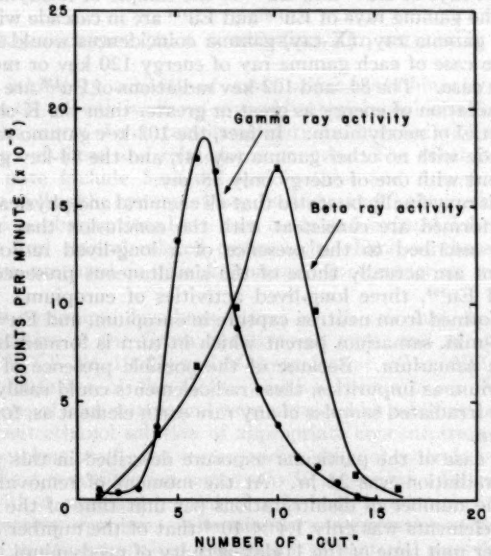

FIG. 1. Beta and gamma-ray activity of cuts of rare earths in solution taken from an ion exchange column. Neutron irradiated neodymium was introduced at the top of the column. The non-coincident maxima illustrate how the gamma-ray activity of the europium contaminants preceded the beta-ray activity of Pm^{147} through the column, showing the gamma rays to be unrelated to any isotope of promethium and to be associated with ions of nuclear charge greater than promethium or, of course, neodymium.

entire cut was employed, while beta-ray observations were carried out by evaporation of three-tenths of 1 cc. of solution upon a backing of Scotch Tape.

To elucidate possibilities indicated by the foregoing investigations, quantities of Eu^{153}, Eu^{154}, and Eu^{155} were obtained from Oak Ridge. Eu^{153} and Eu^{154} were supplied as a mixture, and Eu^{155} was obtainable separately processed. From extensive measurements of the gamma rays emitted by these three isotopes of europium, it was concluded that the gamma ray spectrum of the supposed long-lived gamma-ray emitter was actually a composite one of the three separate gamma-ray spectra

of Eu^{152}, Eu^{154}, and Eu^{155}. The previously described coincidence measurements and critical absorption measurements could now be explained. The X-rays of the unidentified long-period were not emitted following K-capture, but were generated by photoelectric absorption of the gamma rays of Eu^{152} and Eu^{154} in the sample of neodymium itself. Since all the gamma rays of Eu^{152} and Eu^{154} are in cascade with at least one other gamma ray, (X-ray)-gamma coincidences would be observable in the case of each gamma ray of energy 120 kev or more as was indeed the case. The 84- and 102-kev radiations of Eu^{155} are coincident with no radiation of energy as great or greater than the K-shell ionization potential of neodymium. In fact, the 102-kev gamma ray of Eu^{155} is in cascade with no other gamma ray (4), and the 84-kev gamma ray is coincident with one of energy only 18 kev.

Thus, it may finally be stated that all chemical and physical measurements performed are consistent with the conclusion that the effects previously ascribed to the presence of a long-lived radioisotope of neodymium are actually those of the simultaneous presence of Eu^{152}, Eu^{154}, and Eu^{155}, three long-lived activities of europium. Eu^{152} and Eu^{154} are formed from neutron capture in europium, and Eu^{155} is grown from a 23-min. samarium parent which in turn is formed by neutron capture in samarium. Because of the possible presence of europium and samarium as impurities, these radioelements could easily be found in neutron irradiated samples of any rare earth element as, for example, neodymium.

In the case of the particular exposure described in this paper, the time of irradiation was 24 hr. At the moment of removal from the reactor, the number of disintegrations per unit time of the long-lived europium elements was only 1.4×10^{-3} that of the number of disintegrations per unit time of the 11-day activity of neodymium.

If an average half-life of about two years is assumed, for the various europium contributions, from the data of the exposure, a saturation activity (disintegrations per unit time after an infinite time of exposure) just a factor of ten less than the saturation activity of the eleven-day Nd^{147} was calculated. To detect contributions from any radioelement of neodymium of similar half-life, it would be necessary that it possess a saturation activity at least equal to that of the europium impurities, or, in other words, equal to one-tenth that of the eleven-day Nd^{147}.

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THE BIOCHEMICAL RESEARCH FOUNDATION

ELLICE McDONALD, FOUNDER
WILLIAM G. BATT, DIRECTOR

INHIBITION OF BACTERIAL GROWTH BY CERTAIN ORGANIC SULFUR COMPOUNDS

BY

S. J. DECOURCY, JR., F. E. REINHART, AND WILLIAM G. BATT

The inhibitory activity of some sulfur-containing pyridine derivatives on the growth *in vitro* of several bacterial species has been recorded during the course of a current investigation concerned with the biological properties of these and related compounds. The substances reported in this note include 5-nitro-2-pyridinethiol and 6-mercaptonicotinonitrile as well as the corresponding disulfides and S-thiuronium chlorides. In addition, observations have been made on 5-imino-1,2,4-dithiazolidin-3-thione and several related compounds. Each of these compounds had been prepared in this Laboratory in connection with previous studies.

Each compound has been tested on *E. coli* and *A. aerogenes* as representative of the Gram negative rod type, and *M. pyogenes* var. *aureus* (ATCC No. 10617) and *M. pyogenes* var. *albus* (ATCC No. 9491) as representative of the Gram positive coccus type. Various concentrations of each compound were obtained by addition of 0.1 ml. of a 95 per cent ethanol solution of appropriate concentration to 10 ml. of sterile nutrient broth; the corresponding ethanol controls were included. The highest concentration tested was 50 μg per ml. Inoculations were made with a standard loopful of a 24-hour nutrient broth culture of the respective organism. The minimal concentration of the compound required to cause complete suppression of bacterial growth after 72-hr. incubation at 37° C. served as the arbitrary standard of biological activity. The results reported are based on duplicate assay.

None of the compounds which have been tested effected complete inhibition of growth of *E. coli* or *A. aerogenes* when used at the maximum concentration of 50 μg per ml. Some of the compounds, however, manifested activity toward the two variants of *M. pyogenes*, as shown in Table I. With the exception of compound (VIII), somewhat greater sensitivity is seen to be exhibited by *M. pyogenes* var. *albus* as compared to that shown by *M. pyogenes* var. *aureus*.

Activity of each of the nitro derivatives (I, II, III) toward both bacterial variants is seen to be, with one exception, slightly greater than that of its corresponding cyano compound (IV, V, VI). It is evident also that conversion of 5-nitro-2-pyridinethiol (II) or of 6-mercaptonicotinonitrile (V) to its disulfide (I or IV) results in no loss of inhibitory activity.

Inhibitory activity of 5-nitro-2-pyridinethiol (II) toward the growth

TABLE I.

	Compound	Method of Synthesis	Minimal inhibiting concentration in μg/ml. Organism: *M. pyogenes* var. *aureus*	Organism: *M. pyogenes* var. *albus*
I	2,2'-Dithiobis(5-nitropyridine)	(1)	25	10
II	5-Nitro-2-pyridinethiol	(2)	25	10
III	S-(5-Nitro-2-pyridyl)thiuronium chloride	(3)	50	10
IV	6,6'-Dithiodinicotinonitrile	*	50	10
V	6-Mercaptonicotinonitrile	(4)	50	25
VI	S-(5-Cyano-2-pyridyl)thiuronium chloride	(4)	>50	25
VII	S-(2-Pyridyl)thiuronium bromide	(5)	>50	>50
VIII	5-Imino-1,2,4-dithiazolidin-3-thione	(6)	30	40
IX	5-Acetimino-1,2,4-dithiazolidin-3-thione	(7)	>50	>50
X	Potassium trithioallophanate	(8)	>50	>50

* Unpublished data.

in vitro of *Mycobacterium tuberculosis* had previously been noted (9). This thiol and the corresponding S-thiuronium chloride (III) were also found to inhibit growth of *Lactobacillus casei* (ATCC No. 9595) in studies conducted in this Laboratory (10). With respect to the analogous cyano compounds (V and VI), activity toward Gram positive bacteria was observed by Forrest and Walker (4), who noted that these compounds were less inhibitory toward *E. coli*, an observation consistent with the results of the present study.

Although some activity of 5-imino-1,2,4-dithiazolidin-3-thione (VIII), toward both variants of *M. pyogenes* can be seen, none was observed at the 50 μg level with its acetyl derivative (IX) or its reduction product (X). Similar lack of inhibitory activity was found with S-(2-pyridyl)thiuronium bromide (VII) at this level.

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THE FRANKLIN INSTITUTE LABORATORIES
FOR RESEARCH AND DEVELOPMENT
NICOL H. SMITH, DIRECTOR

REACTIVITY COMPUTER

BY

GILBERT S. STUBBS

The basic, underlying variable of reactor control is the reactivity. We may regard the reactivity as a measure of the deviation from equilibrium of the neutron balance in a reactor. Or more precisely, we may define the reactivity as the average excess number of neutrons produced per fission that cause further fission, "excess" being the number over and above the one-neutron-per-fission that is required to maintain a self-sustaining fission reaction.

Reactor control may be described as the process of changing the neutron environment within a reactor so as to produce momentary excursions in the reactivity from its equilibrium value of zero.

FIG. 1. The author examines a graphic record-of-reactivity produced by reactivity computer in conjunction with a standard recorder.

An analog computer which computes these variations in reactivity of an operating reactor was demonstrated by the Laboratories' Nuclear Engineering Division at the Second Nuclear Congress at Convention Hall, Philadelphia, March 11–15. This computer, referred to as the "Reactivity Computer," is based on the fact that the time behavior of the reactivity is related to the time behavior of the reactor's neutron flux through a group of simultaneous differential equations, called the "reactor kinetic equations." The computer duplicates these equations in terms of voltages and currents, and operates on electrical signals derived from neutron flux measurement to generate a voltage proportional to reactivity. The Reactivity Computer was operated at The Franklin Institute exhibit with a neutron flux signal from an instrument in the Aerojet-General Nucleonics Reactor, which was exhibited and operated during the Congress.

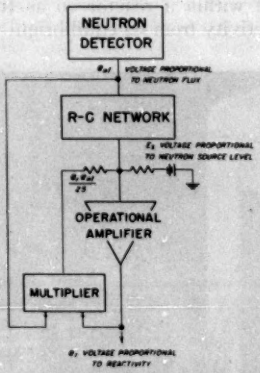

FIG. 2. Block diagram of a typical reactivity computer employing neutron flux input.

A recently published paper[1] describes two types of reactivity computers which have been built by the Nuclear Engineering Division—one employing a neutron flux input signal, the other employing a log-rate-of-neutron-flux input signal.

Some applications of the Reactivity Computer are:

(1) for measuring and recording reactivity
(2) as a feedback element in reactor control systems

[1] G. S. STUBBS, "Design and Use of the Reactivity Computer," *IRE Professional Group on Nuclear Science*, Vol. NS-4, No. 1 (1957).

(3) as a reactivity-monitoring device for reactor safety controls
(4) for calibrating control rods
(5) as a tool in reactor frequency response measurements
(6) for measuring the reactivity coefficients
(7) for measuring the neutron generation time and the delayed neutron constants
(8) for indicating criticality during reactor start-up
(9) as a tool in reactor kinetics experiments
(10) as an analytical tool for theoretical studies of reactor kinetics.

BOOK REVIEWS

AERODYNAMIC COMPONENTS OF AIRCRAFT AT HIGH SPEEDS, edited by A. F. Donovan and H. R. Lawrence. Volume VII of the Princeton Series for High Speed Aerodynamics and Jet Propulsion, 843 pages, tables and graphs, 6 × 9¼ in. Princeton University Press, 1957. Price, $17.50.

This book is Volume VII of the Princeton Series for High Speed Aerodynamics and Jet Propulsion. This twelve volume undertaking treats the fundamental aspects of the aerodynamic and propulsion problems of high speed flight together with a survey of the underlying basic sciences cognate to such problems. The present volume is a valuable addition to those volumes which have appeared to date. Some one hundred scientists and engineers active in aeronautics and related fields have participated in this series. Ten prominent workers including the editors contributed to the seven sections of Volume VII.

Section A was prepared by Robert T. Jones and Doris Cohen of the National Advisory Committee for Aeronautics. This section is devoted to the aerodynamics of wings at high speeds. Beginning with a review of wing theory for low speeds the reader is led through a development of the concepts of compressibility, sweepback and thin airfoil theory up to the treatment of supersonic wing theory. The theory is developed in lucid detail and useful tables are provided for determing flow fields adjacent to supersonic wings. This section alone could serve as a useful reference for the practicing aerodynamicists as indeed it probably will.

Section B is entitled "Aerodynamics of Bodies at High Speeds" and is a logical companion of Section A. Clinton E. Brown of the National Advisory Committee prepared this summary of body aerodynamic theory and has done it well. Beginning with a development of the potential flow theory for supersonic flow around bodies of general cross-section the author takes us through pressure drag laws and comparisons with experiment. The use of potential theory to obtain lift distribution and dynamic stability force and moment aerodynamic coefficients is illustrated. This reviewer was left with the feeling that the author may have created the impression that the potential theory is more successful for bodies than the experiments indicate. The reviewer was also surprised to find that the earliest contributors to this theory, Von Karman and Moore, Tsien, and Ferrari, were not referenced although their contributions are surely almost universally recognized. The aerodynamics of hypersonic flow around bodies, including shock-expansion theory, and the exact solutions for supersonic flow around cones were also conspicuous for their absence though perhaps they are being left for other sections of other volumes.

Section C, "Interaction Problems," falls in proper order after Sections A and B. C. Ferrari, a pioneer in this field, contributed this section. Beginning with a description of the problem, the author treats wingtail interference, wing-body interference and propeller and wing interactions at subsonic speeds followed by a treatment of the first two problems at supersonic speeds all within the framework of linear theory. Where possible, comparisons between experiment and theory are presented. There is no denying that interaction problems are difficult at best and the mathematic treatment displayed matches the problem. This section presents the most comprehensive treatment of this problem area known to the reviewer.

Section D was refreshing to find in a volume devoted to high speed aerodynamics and jet propulsion. Entitled "Propellers for High Speed Flight," it was prepared by C. B. Smith of the Pratt and Whitney Division of the United Aircraft Corporation. Starting with simple blade element theory the author proceeds to develop propeller thrust and torque relations and then, having developed the tools to do so, illustrates the principles of propeller efficiency, optimum propeller pitch distribution for given engine

power setting and the concept of an ideal propeller. The effects of supersonic flight on propeller efficiency are treated briefly.

"Diffusers and Nozzles" is the title of Section E prepared by J. C. Evvard of the National Advisory Committee for Aeronautics. Starting with a development of one-dimensional flow equations which serve admirably to illustrate the features of compressible, nonadiabatic flow through diffusers and nozzles, the author discusses the effects of viscosity, boundary layer separation and diffuser geometry on diffuser efficiency. Supersonic diffusion processes, diffuser performance, sources of pressure recovery losses and their remedies are discussed in detail. The aerodynamics of exit nozzles and jets are dealt with along with their implications with respect to jet thrust. Perhaps the complexity of the problem and the lack of data available prevented the presentation of more experimental data which the reviewer thought was lacking.

Section F was prepared by I. E. Garrick of National Advisory Committee for Aeronautics and is entitled "Nonsteady Wing Characteristics." Beginning with a derivation of the differential equations for steady flow the author establishes a basis for linearizing them, develops a velocity potential (time dependent) and establishes the nature of the boundary conditions for moving surfaces. Simple solutions for subsonic and supersonic flow about two and three dimensional wing surfaces are developed. Especially pleasing is the effort made to graphically illustrate the analytical concepts. Relations for use at hypersonic speeds and at sonic speeds are presented and discussed. An ample discussion of experimental techniques used rounds out this valuable contribution along with the extensive list of references and the bibliography.

The volume concludes with Section G entitled "The Experimental Aerodynamics of Wings at Transonic and Supersonic Speeds." This section was prepared by C. W. Frick of the National Advisory Committee for Aeronautics. We find here much of the comparison of theory with experiment the reader may desire after reading the preceding sections. Some attention is paid to transonic similarity laws and their use for correlating data is illustrated. Direct comparison between theory for the simpler planforms treated in earlier sections and experiment serves to demonstrate the value of the theory for estimating lift and pressure drag. Where failings of the theory exist, they are illustrated also. The agreement between theory and experiment, when it occurs, is gratifying to behold. The reviewer wished that this section could have been expanded to include comparisons between body theory and experiment.

It is difficult, perhaps even presumptuous, to find fault with this volume which represents a formidable undertaking. The reviewer found the numbering system for the figures and illustrations tedious but realized that the system was devised to simplify reference to figures used in other sections. A more demanding confrontation of the many aspects of potential theory presented so elegantly throughout this volume with appropriate experimental data would have helped the reader to put this valuable theory in proper perspective. Nevertheless, this volume compares favorably with its companion volumes and is a valuable addition to the library of the aeronautical specialist.

WILLIAM H. DORRANCE
Convair

THE NEW WORLD OF THE ATOM, by James Stokley. 288 pages, plates, 5¾ × 8½ in. New York, Ives Washburn, Inc., 1957. Price, $5.50.

Human understanding of the great new force—atomic energy—is a necessary condition for viewing it in its proper perspective. A writer who attempts to detail this in a book tackles a problem of staggering proportions. Not only must the past with its historically significant background be revealed but the present day picture—the state of the art today—must be drawn. From this point the author must speculate on the aspirations of the future. In a field as fertile as atomic energy into which at least $14 billion has been funnelled; in a field where activities have increased from a few scientists in academic institutions to hundreds of thousands of scientists, engineers, mathematicians, administrators and laborers in hundreds of academic and industrial establishments all over the world; in a field which at the start merited little attention to one which influences the lives of every man, woman and child on the

earth, the ability to sort and cull the important developments for inclusion in a book is the mark of a skillful writer.

In *The New World of the Atom*, Dr. James Stokley, one of the ranking science writers in the United States, has shown the progression from the concepts of Democritus to the atom as the key to our welfare and energy of the future.

The author has divided his book into four parts.

The first part is a magnificant exposition of the history of the atom in which he shows that our understanding was built on speculations which originated millenia ago. Details of the work done in the early 19th century and the phenomenal strides made at the close of the century are given. In all this writing there is a warm intimate approach. For example, when the author writes about Roentgen and his discovery of X-rays, he writes ". . . someone asked Roentgen what he thought when he noticed this strange effect.

"His reply has become classic—the response of a true scientist:

"'I did not think,' he said, 'I investigated.'"

In the 1920's there was a concerted attack on the nucleus and in the early 1930's came the atom-smashers. The descriptions of the devices and their operation are complete and impressive, as is the story of fission and the building of the bomb.

Part II involves the atom as a source of power. Today we would like to believe that the greatest effort in the atomic energy field is directed toward this goal. Dr. Stokley opens this section with an outline of the energy needs of the future and the energy potential of nuclear fuels. In this section the author relies on the work of Palmer Putnam perhaps too strongly. Here are found complete descriptions of the various types of reactors. The experience of the author gained as one engaged by the U. N. to prepare background material for the International Conference on the Peaceful Uses of Atomic Energy held in Geneva in 1955 is in evidence. With this background he has been able to include the work in other countries—primarily Russia. It is curious how opinions credit only the major powers like the U. S., England and Russia with the ability to create the plants for atomic power. Yet, the author shows that smaller countries like Sweden and Canada are also engaged in both fundamental research and development of reactors.

Section III deals with the impact of atomic energy. The revolution in ship propulsion is discussed. The possibility of nuclear powered aircraft and locomotives and even the application to space travel is detailed. It is refreshing to find the author *not* offering this type of energy as the ultimate for rockets. The role of atoms in industry is new but its impact has rocked our modern technology. It is used to create materials, to gauge thicknesses, to determine wear, to make radiographs, to check flow in pipe lines, to detect pollution (to name a few fields where the atom has found work). In all probability the atom will play some role in every major undertaking of man in the future. There is a fascinating chapter on the atom in agriculture. The use of the atom as a weapon in the struggle with insects, its use as a gauge to show availability and consumption of fertilizer, the atom as a device to induce favorable mutations to create disease-resistant crops and its use to preserve foods are described. The last chapter in this section deals with the use of the atom in biology and medicine and in radiocarbon dating.

The final section deals with the political implications of the new force. The author describes the change in thinking which has finally permitted our scientists to meet with those of other countries—including Russia—for frank discussions on the atom. President Eisenhower's dramatic announcement before the U. N. on the peaceful application of the atom and the implementation of this by the offer of large amounts of fissionable material are detailed.

The New World of the Atom is a brilliantly conceived, superbly written book on the atom.

I. M. LEVITT
The Fels Planetarium

THEORY OF LAND LOCOMOTION, by M. G. Bekker. 520 pages, diagrams, 6 × 9 in. Ann Arbor, University of Michigan Press, 1956. Price, $12.50.

Several years ago this reviewer was engaged in research on the cross country mobility of artillery vehicles for the U. S. Government, and consequently knows some of the

problems of land locomotion. In the course of his research, he came to know Col. Bekker and was much impressed with his knowledge of the mechanics of vehicle mobility. It is gratifying to know that his experience and knowledge are now available in book form. This book would have been quite useful when the above mentioned research was being conducted, for it contains a great deal of information on the whole broad field of off-the-road locomotion.

Much of Col. Bekker's career has been devoted to the study of land locomotion. Formerly an officer in the Canadian Army and head of its Motor-Vehicle Laboratory, one time research professor at Stevens Institute of Technology and head of their Motor-Vehicle Laboratory, he is now at the Detroit Arsenal where he has established a land locomotion laboratory. His knowledge and sincere interest in the improvement of cross country transportation are constantly reflected in his book. Beginning with an interesting study of locomotion in nature where, among other things, he reduces an animal's movement to mathematical expressions, he proceeds to the study of the development of the wheel from early times through the present to ways of future progress, and on to the morphology of motor vehicles amd environment where the form, size and mobility of vehicles are discussed.

In the study of vehicle transportation it is essential to know something of the mechanics of the supporting media, and so Col. Bekker reviews the basic, pertinent soil and snow mechanics. Thorough discussions of the action of wheels and the crawlers of track-laying vehicles over all types of terrain, and of the motion of skis, sleighs and toboggans follow. Having analyzed the rolling or sliding parts of a vehicle, Col. Bekker then treats the vehicle as a whole and enumerates the significant facts that must be considered in cross country travel. The field is so great that in most cases he is able only to pose the problem and suggest paths of further research, rather than to offer a solution. Knowing something of the basic mechanics of soils and behavior of wheels and vehicles, the problem next is the prediction of the performance of vehicles in unknown terrain. Various attempts have been made to develop instruments to predict the trafficability of soil, but with only limited success. Those and related items in the economy of transport are described in the chapter on trafficability, performance and economy of locomotion. A chapter on scale-model testing and one on dimensional theory conclude the book.

Much of the information in *Theory of Land Locomotion* is available, but in widely assorted places. Almost 350 references are listed at the end of the book. A real service has been performed in bringing the data together in an orderly arrangement, and in outlining the problems that must be faced in the improvement of cross country transport. In many instances, Col. Bekker also has pointed out the logical way in which this improvement may be sought.

E. W. HAMMER, JR.
The Budd Company

THE CHEMISTRY AND TECHNOLOGY OF LEATHER. VOL. I. PREPARATION FOR TANNAGE, edited by Fred O'Flaherty, William T. Roddy and Robert M. Lollar. ACS Monograph No. 134. 495 pages, illustrations, 6 × 9 in. New York, Reinhold Publishing Corp., 1956. Price, $14.00.

The Chemistry and Technology of Leather is a four-volume monograph covering the various technical aspects of tanning and leather manufacture from the pre-tanning stage to the finished product, the four volumes being: Preparation for Tannage, Tannage, Process Control of Quality Leather, and Leather Properties.

Since, by Webster's definition, a monograph is a special treatise on a special subject, we find that the editors have deviated somewhat from this interpretation. However, since the field is broad in scope, it has been subdivided into smaller logical units, thus actually fulfilling the requirements of a monograph and at the same time permitting a greater latitude in the selection of topics. These monographs were compiled to serve a dual purpose: first, to provide a complete source of information for the chemist or technologist interested in a field either directly or indirectly related to his immediate activity; second, to arouse further scientific activity in the various phases of leather chemistry. Since the nature of the work is so diversified and since so much has appeared in the literature, it would have been

unwieldy to incorporate all the information available on a general subject and still maintain a compact volume. Instead, each contributor has listed a series of references at the end of his discussion from which the interested reader can gather more complete information and have easy access to original work. In the editors' attempts to present a truly authoritative series of monographs, they made the contributorship international in scope. Where common areas of understanding existed these are now more vigorously confirmed; where there are conflicts these are now exposed for further scrutiny; and where fact is not existent this too is indicated. This, then, is the pattern from which this monograph has been fashioned.

Volume I, entitled "Preparation for Tannage," covers the theoretical aspects of skin chemistry as well as the more practical ones of Beamhouse operations. For examples, the chapters on Non-Protein Constituents of Skin, Chemical Structure and Macromolecular Organization of Skin Protein, Acid and Base Binding Properties of Proteins are theoretical in consideration and would be of more value and interest to the chemist or scientist than to the technologist. For those such as the technologists who are probably more interested in practical applications, there are chapters on Preservation of Hides, and Skins, Washing and Soaking, Practice of Unhairing, Practice of Bating, Pickling, and Skin Degreasing. In the intermediate range, one in which the chemist and technologist have common interests, there are chapters on Histology of Animal Skins, Chemistry of Liming, and Bating. In reading the book one becomes aware of overlapping of subjects in the various chapters. However, this feature enhances the value of the monograph since it more strongly inter-relates the functions of the various steps in preparing skins for tannage, and shows where theory and practice can be combined to ultimate advantage.

The chapters on Practice of Unhairing and Mechanism of Unhairing are representative of the quality and value of this volume. In the former chapter, the author, Wendall Harris, discusses in detail various chemical techniques used in the removal of hair and their applications. The technique used is dependent upon the source from which the skin or hide is obtained and the grade of leather desired. He also describes which chemical techniques are most advantageous for the recovery or destruction of hair. In the latter chapter, the author, Henry B. Merrill, frankly admits that no one has yet explained the exact mechanisms involved in depilation. In his discussion on the mechanism of hair destruction, however, he indicates that this is fairly well understood. As a general introduction to the chapter, he talks about the histology of hair and the chemistry of keratins, the single most important constituent of hair. He then discusses the mechanism of hair destruction through the action of alkalies and sulfides (and other reducing agents) and points out the phenomenon of immunization. Hair, when exposed to alkali for short periods will no longer be rapidly attacked by otherwise totally destructive sulfides. Following this explanation, he theorizes, based on practical observations, on seven processes used in loosening hair. A summary concludes this chapter in which he expresses the hope that some day the mechanism of unhairing will be understood.

In view of the quality of the information contained in this volume and the skill which the editors have applied in its compilation, this reviewer is looking forward to the succeeding volumes. A work of this caliber should be a welcome addition to the library of a chemist, technologist, or any one interested in the production of leather.

MARVIN PACKER
The Franklin Institute Laboratories

ENGINEERING USES OF RUBBER, edited by A. T. McPherson and Alexander Klemin. 490 pages, illustrations, 6 × 9 in. New York, Reinhold Publishing Corp., 1956. Price, $12.50.

Engineering Uses of Rubber is an informative book on the applications of rubber as a material of construction in many diversified engineering fields—civil, mechanical, electrical, and chemical. As in other books of this type—one which is edited rather than authored—each chapter is written by an authority on a particular topic, thus lending added significance to the individual discussions. Each author, wherein possible, has pointed his discussion on the application of rubber through a better understanding of fun-

damental properties. This gives the reader a deeper appreciation of rubber as a material of construction so that he may better qualify to utilize this product to its fullest advantage. There is sufficient and diversified information in this book that makes it of interest to anyone who finds himself in a position where the use of rubber is indicated whether he be specialized engineer or a materials engineer. The rubber technologist or anyone connected with the manufacture of rubber will also find valuable information contained herein.

The introduction relates the history of rubber, and briefly explains how the different types of rubbers are made. The author also attempts to differentiate between what is commonly called rubber and synthetic rubber or elastomers. In subsequent chapters we find discussions on the compounding and manufacture of rubber, and the effect of the individual ingredients comprising a formulation on the end properties of rubber. The chapter General Engineering Properties of Rubber concisely discusses stress-strain characteristics and its ramifications and the various moduli, elasticity, compression, shear, and bulk (volume compressibility). The usual physical properties are discussed as well as test procedures such as tensile, tear, and hardness.

There is a chapter on The Design of Rubber Mountings which explains how the tension, shear, and compression properties of rubber are to be evaluated in any design. The chapter on Deterioration of Rubber from Use and with Age discusses the effects of environment on rubber. The chapters on rubber in the fields of Civil, Electrical and Chemical Engineering show which properties are extremely important in selecting a certain rubber for a given application. The various types of rubber discussed are: Natural, Butadiene-styrene (GR-S), Butyl, Nitrile, Neoprene, Polyvinyl Chloride, Thiokol, Silicone and Acrylate. Some plastics such as polyethylene, nylon, teflon and mylar are also included and are compared to rubber.

No book on rubber would be complete without a chapter on tires, and in this one the author has described the physical properties of good tire rubber, its construction, and manufacture. The uses of rubber in conveyer belts, in aviation, and for new or special purposes (e.g., cements) are also discussed in other chapters. A chapter devoted to Specification and Inspection of rubber products discusses the various test procedures, how to prepare specifications and why they are necessary, and the method and function of sampling.

The last chapter entitled Molecular Structure and Mechanical Properties of Polymers attempts with the aid of rheology to show the relationship between molecular structure and mechanical properties. This last chapter is too brief in its treatment of so difficult a subject although what the author has discussed has been done well.

MARVIN PACKER
The Franklin Institute Laboratories

STRESS CORROSION CRACKING AND EMBRITTLEMENT, edited by William D. Robertson. 202 pages, illustrations, 6 × 9 in. New York, John Wiley & Sons, Inc., 1956. Price, $7.50.

The Symposium on Stress Corrosion Cracking, arranged by the Corrosion Division of the Electrochemical Society, was held at Boston in October, 1954, exactly ten years after a symposium on the same subject, sponsored by the American Society for Testing Materials–American Institute of Mining and Metallurgical Engineers. The preceding collection of papers demonstrated that the phenomena of cracking were observed in many alloys and chemical environments; nevertheless, failure in service was not generally a limiting factor in designing structures, and, in some alloys, the mechanism was sufficiently well understood so that appropriate alloys or heat treatments could be specified to avoid failure.

The experience of the past ten years has shown, however, that in some instances stress corrosion cracking has become a limiting factor in design. Inevitably, this has occurred in alloy systems in which the mechanism of cracking is not well understood and under conditions in which alloys are called upon to perform close to the present limit of their mechanical and corrosion-resistant properties. On the other hand, in the past ten years, our knowledge of the structure of metals and alloys has increased tremendously. In view of the pressing demand for solutions to this problem and the availability of new ideas and experiments, the time seemed ap-

propriate to reconsider the problem and, in particular, to concentrate on those areas where the previous symposium has indicated only a limited understanding of mechanism.

The 14 papers presented in this symposium discuss the phenomena and mechanism of stress corrosion cracking, structural factors, boundary adsorption, effects of hydrogen, and investigations of stress corrosion cracking in various metals.

SAMUEL F. ETRIS
American Society for Testing Materials

ANNUAL REVIEW OF NUCLEAR SCIENCE. VOLUME 6. 1956, edited by J. G. Beckerley. 471 pages, diagrams, 6 × 8¾ in. Palo Alto, Annual Reviews, Inc., 1956. Price, $7.00.

This 1956 volume is similar to those of the past in its broad spectrum coverage in nuclear science, in its general usefulness, and in its general excellence of articles. Thirteen articles originating from eleven American, one Indian and one German laboratory cover such diverse subjects as cosmic rays, radiation effects in solids, reactors, nuclear data, techniques, isotope effects, nucleon polarization, and radiobiology.

Most of these review articles are critical, thorough surveys wherein theory, experiment and their interrelationship are discussed. Of all of the articles, only the one on oxygen isotope applications tends toward being an annotated bibliography, and it is to be noted that the author complained of space limitations. All of these articles are useful, as before, in that they supply workers in specific fields with discussions of recent literature and in that they supply modern surveys for the non-specialist. It should be noted that there are over 1300 references.

Several of these reviews restrict themselves to covering the last four or three or one year, that is, to the interval since the last review. But this does not mean that such reviews will be bare of discussions of fundamentals. The exact converse is true in the cases of the surveys in cellular radiobiology and radioactive effects. These are the longest in the book, have the most references, and cover subjects of intensive current research. Both articles discuss advances in our knowledge of fundamental principles in these fields.

If there is something to criticize it is that less than half of the surveys have some form of summary which might inform the reader (and make life easier for the reviewer) as to what direction we are moving and what current or future research may tell us.

The titles of the articles are: Time Variations of Primary Cosmic Rays, Polarization of Fast Nucleons, Excitation of Nuclei by Charged Particles, Isotope Shift in Atomic Spectra, Properties of Medium-Weight Nuclei, Generalized Acidity in Radiochemical Separation, The Masses of Light Nuclides, Nuclear Radiation Effects in Solids, Applications of Oxygen Isotopes in Chemical Studies, Recent Advances in Low Level Counting Techniques, Nuclear Reactors for Electric Power Generation, Cellular Radiobiology and Vertebrate Radiobology: Embryology.

LEONARD MULDAWER
Temple University

BOOK NOTES

THE HANDBOOK OF ROCKETS AND GUIDED MISSILES, by Norman J. Bowman. 328 pages, diagrams, 5½ × 8½ in. Chicago, Perastadion Press, 1957. Price, $6.50.

This is an excellent reference book for those interested in rockets, guided missiles and space travel. It is divided into two sections. The first deals with various types of missiles, jet motors, rocket motors and finally satellites.

The second section is of significant value to the engineer for all available data on rockets and guided missiles are given together with outline drawings.

A complete reference section gives the source of data used.

The appeal of this book is limited but to those engaged in some facets of rockets and guided missiles fields it is of inestimable value.

INVENTORS AND INVENTIONS, by C. D. Tuska. 174 pages, diagrams, 6 × 9 in. New York, McGraw-Hill Book Co., Inc., 1957. Price, $3.75.

The author, Director of Patent Operations at RCA Laboratories, has expanded the theses set forth in two JOURNAL papers to a full-length book on *Inventors and Inventions*. He begins with the inventions of primitive man (clothing, weapons, tools), and proceeds to a discussion of how environment influences invention. This chapter plots the number of patents granted per state (in the U. S.) plotted as a function of general population, of professional society population, of average temperature; the author then develops the thesis that contact with other scientists and inventors is of importance to the "new" inventor. In the section on Education and Invention, the author points out that in a study of 1000 patent applications filed for 100 inventors, 44 of the 100 had the B.S. or B.A. degree, 25 had an M.S. or M.A., 21 the Ph.D. and 10 had no degree. Other topics covered in an equally readable style are: Age and Sex of Inventors (most productive years are 35-39); Psychology of Inventors; and Methods of Inventing.

Separate chapters are devoted to these various approaches to invention: Experiment—Happy Accident—Serendipity; The Direct, Painstaking Approach; Synthesis—Imagination—Foresight; Scientific Curiosity—Eagerness to Learn—Pioneer Spirit. Each of these four chapters contains historical examples of inventors who solved their problems using the method under discussion.

The remainder of the book discusses patentable inventions, patent law, preparation of patent applications and marketing of the invention. An appendix reviews and discusses several law cases involving patents.

THE PRESENTATION OF TECHNICAL INFORMATION, by Reginald O. Kapp. 147 pages, 5 × 7¼ in. New York, The Macmillan Co., 1957. Price, $1.95.

First published in England in 1948, this useful series of lectures is now available in the United States. The lectures are aimed at technical people, to help them improve their written reports and articles. Fifteen short chapters cover such topics as: functional English and its problems; choice of material; making it easy to understand; on meaning what you say; etc. By following the author's suggestions, technical men should be able to write their reports in a more commanding way.

HANDBOOK OF SOLVENTS. VOLUME 1: PURE HYDROCARBONS, by Ibert Mellan. 249 pages, 6 × 9 in. New York, Reinhold Publishing Corp., 1957. Price, $6.50.

This is the first volume in a proposed several volume work on the composition and properties of industrial solvents, compiled for workers in industries using solvents. Written by an expert with 25 years of experience in chemical industry, this first volume covers all types of pure hydrocarbons—aliphatics, aromatics and terpenes. To facilitate ready use, commercial and proprietary names are used instead of chemical nomenclature. The hydrocarbon solvents are classified according to distillation range, and their properties recorded in tabular form.

After an introductory chapter covering pertinent general interest topics (coal, evaporation rate, gravity, safe handling, vapor pressure, etc.), each of the three major classifications mentioned above occupies a section of

the book. Within each section, each solvent discussed occupies one page of text. Since the solvents are listed by order of distillation range, the easiest way to locate a particular solvent is to look it up in the index, for there is a wide overlap in the distillation ranges. In future editions, it might be well to set off the names of the solvents in boldface type.

EXPERIMENTAL PSYCHOLOGY AND OTHER ESSAYS, by I. Pavlov. 653 pages, plates, 5½ × 8¼ in. New York, Philosophical Library, 1957. Price, $7.50.

This comprehensive anthology of the writings of the great Russian physiologist, Pavlov, will prove of interest to physiologists and psychologists as a record of one of the 19th century's greatest experimenters in the field of physiology. An introductory section by Kh. S. Koshtoyants evaluates Pavlov's works; a second section is Pavlov's autobiography. The rest of the volume contains Pavlov's lectures, papers, etc., covering works on blood circulation, digestion, nervous activity, sleep, hypnosis and psychology. A final section contains excerpts of Pavlov's statements at the "Wednesday" gatherings.

THE SUN, by Giorgio Abetti, translated by J. B. Sidgwick. Third edition, 336 pages, plates, 5½ × 8½ in. New York, The Macmillan Co., 1957. Price, $12.00.

In 1934 one of the most authoritative books to appear on the sun was published. The author, Giorgio Abetti, maintained his own observatory at Arcetri, Italy where the sun was the principal celestial object under study. From his first hand knowledge of the sun, Professor Abetti contributed a chapter on solar physics to the "Handbuch der Astrophysik" which he later enlarged into his book.

Today, twenty-two years later, the third edition is off the press. It brings the former work up-to-date and incorporates the latest findings from researchers all over the world.

Just as it was a must in the early days, so it fills a need today for a single comprehensive work on the sun and solar physics.

PUBLICATIONS RECEIVED

The Editors wish to call attention to the following books, received in the JOURNAL office for review. Lack of space prevents publication of reviews.

MODERN PULP AND PAPER MAKING, by John B. Calkin. Revised third edition of a work previously prepared by George S. Witham. 549 pages, illustrations, 6 × 9 in. New York, Reinhold Publishing Corp., 1957. Price, $10.00.

ELECTRICAL SYSTEMS DESIGN, by Joseph F. McPartland and the Editors of *Electrical Construction and Maintenance*. 140 pages, 8½ × 11 in. New York, McGraw-Hill Book Co., Inc., 1957. Price, $6.00.

FOUNDATIONS OF RADIO, by M. G. Scroggie. Sixth edition, 349 pages, diagrams, 5½ × 8½ in. New York, Philosophical Library; London, Iliffe & Sons, Ltd.; 1957. Price, $10.00.

ELEMENTARY PRACTICAL ORGANIC CHEMISTRY, PART I, SMALL SCALE PREPARATIONS, by Arthur I. Vogel. 361 pages, diagrams, 5½ × 8½ in. New York, Longmans, Green and Co., Inc., 1957. Price, $4.50.

THE HISTORY OF MATHEMATICS, by Joseph E. Hofmann. 132 pages, 5½ × 8 in. New York, Philosophical Library, 1957. Price, $4.75.

BOY'S BOOK OF FROGS, TOADS AND SALAMANDERS, by Percy A. Morris. 240 pages, illustrations, 5½ × 8½ in. New York, The Ronald Press Company, 1957. Price, $4.00.

RUTHERFORD, ATOM PIONEER, by John Rowland. 160 pages, 4¾ × 7¼ in. New York, Philosophical Library, 1957. Price, $4.75.

ELEMENTARY THEORY OF STRUCTURES, by Chu-Kia Wang and Clarence Lewis Eckel. 387 pages, diagrams, 6 × 9 in. New York, McGraw-Hill Book Co., Inc., 1957. Price, $7.50.

Completely Transistorized Computer.—The Government and Industrial Division of Philco Corporation is constructing the first of two completely transistorized TRANSAC S-2000 computers to be delivered in 1958. TRANSAC Type S-2000 is a large scale completely transistorized Electronic Data Processing System designed for on line and off line commercial, scientific and military applications. Incorporating a combination of transistors and printed circuitry, first developed by Philco to meet the rigid requirements of airborne control systems, this system is designed to offer the advantages of extreme compactness, light weight, low power consumption, high speed and extreme reliability.

The highly developed Philco transistors, unlike vacuum tubes, require no periodic replacement thereby greatly decreasing the problems of preventive and operative maintenance. Generating comparatively little heat, the S-2000 requires only a small fraction of the air conditioning equipment normally required for large scale computers—in fact, only the amount of cooling normally needed for human comfort is sufficient, as compared to the requirements of some current systems using up to 40 tons of air conditioning.

Ready to operate upon delivery, the TRANSAC S-2000 computer portion of the system will entail no installation work or special power wiring and may be plugged into existing 110 volt, 60 cycle convenience outlets.

Because the air conditioning and power requirements are negligible and because the TRANSAC computer weighs only 6000 lb., a saving of up to $250,000 in installation costs is possible through the use of a Philco TRANSAC S-2000 system.

The system consists of the central computing unit, a paper tape input and output similar to teletype and magnetic tape units. These magnetic units use tape similar to that used on home or commercial tape recordings. The computer also has a magnetic core memory for hi-speed internal storage (256,000 characters of information) and can perform 39,000 additions per second, 39,000 subtractions per second, 12,000 multiplications per second or 10,000 divisions per second.

The magnetic tape is made of plastic and is 2400 ft. long containing over 5 million alphabetical or numerical characters or the equivalent of 65,800 fully punched, eighty column, tabulating cards requiring five filing cabinets for storage.

The computer will accept information from the tape at the rate of 15,000 alpha-numeric characters every second and can write on the tape at the same speed. This is equivalent to "reading" the dictionary in approximately seven minutes.

A hi-speed printer used with this system could print at the rate of 600 lines per minute or 10 computer lines of 120 characters each every second, which is the equivalent of printing over 4 million characters every hour. As an example, the printing of payroll checks with 6 lines of information per check could be done at the rate of 100 checks every minute or the entire payroll for 10,000 employees in less than two hours. (It would take a typist 30 days to complete this task.)

The complete Philco system will occupy no more space than 250 sq. ft. and could be placed on a 15 × 15 ft. rug. Many present day systems re-

quire up to 4000 sq. ft. or an area equivalent to two medium sized ranch homes.

Philco's TRANSAC S-2000 Electronic Data Processing System is available on a variety of purchase or rental plans.

Prefabricated Sound Enclosure Reduces Transformer Sound Level.—At Schenectady, N. Y., the Niagara Mohawk Power Corporation has installed what is believed to be the world's first transformer with a prefabricated sound enclosure. Tailor-made, the sound enclosure has resulted in a 19.6-decibel sound reduction for this 5000-kva, 34.5 General Electric transformer.

The oil-filled, load-tap-changing transformer was specifically engineered by the company's Medium Transformer Department, Rome, Ga. It is the first integrated transformer and sound enclosure capable of being fully assembled and pre-tested at the factory.

Core and coil assembly are of conventional design in all particulars but the tank which is completely encased in an additional steel sound enclosure, according to General Electric design engineers. Cooling tubes are mounted in a separate external tube bank and connected to the transformer by four resilient oil pipes. The transformer tank and sound enclosure are mounted on a common concrete pad. Vibration isolation of the two components is accomplished by resilient tank mounts and by a rubber diaphragm assembly at each of four high-voltage cover bushings, at one cover-mounted pressure relief device, and at each of four tank-to-tube-bank oil pipes. The tube bank is mounted on an extension of the transformer's foundation pad.

The sound enclosure is of one-piece, all-welded construction with what General Electric engineers call a "moderate amount" of internal and external bracing to provide enough rigidity for easy handling at the factory and in the field. Principal accessories and the load-tap-changer mechanism are grouped together on the low voltage side of the tank and are accessible through hinged and bolted enclosure openings. Small glass windows are provided for observation of indicator dials.

Glass fiber bats are used to help decrease the sound level. Some of the bats are mounted on the inner sides of the enclosure while others are mounted on the outer surfaces of the transformer tank. In order to minimize their thermal insulating effect, all bats are spaced at least one inch from the surface on which they are mounted, engineers said.

General Electric engineers say that this initial installation does not represent the ultimate in noise reduction. Similar enclosures can be made to reduce the sound level of a transformer by upwards of 20 decibels.

Atomic Radiation Increases Burning Speed of Fuels.—The possibility that atomic radiation can be used to make fuels burn faster in aircraft or rocket engines has been raised by a University of Michigan chemical engineer. Associate Prof. Stuart W. Churchill told the 131st national meeting of the American Chemical Society that experiments at The University of Michigan had shown radiation from a powerful bit of radioactive gold can increase the burning speed of fuel by 50 per cent.

The discovery means that smaller engines with radioactive "sources" might be used to do the job of bigger ones, Professor Churchill said. Since every pound saved in a component of an aircraft means an additional saving of ten pounds elsewhere in the plane,

the announcement is expected to be of considerable interest in the aeronautical field.

Conceivably aircraft, rockets or missiles could be equipped with radiation sources to whittle down engine weight and the space required for the combustion process. The discovery also suggests existing engines could be made more efficient or could operate at higher altitudes.

Professor Churchill emphasized the study was a preliminary one, and that the results show an increase in the burning speed of a given amount of fuel, rather than an increase in power from it.

He attributed the success of the test to the fact that the source employed had a rating of 10,000 curies—one of the most intense ever used for irradiation purposes.

He said the radiation given off by the gold—beta particles, or the "satellite" electrons from gold atoms—caused certain parts of the fuel to be more reactive chemically, and to burn faster.

The results were roughly the same for all the fuel-air mixtures tried and at pressures ranging from those found at 30,000 ft. and 50,000 ft. altitude, he said.

Investigations of the ways different types of radiation effect combustion have been made before, Prof. Churchill noted, but because of the greater strength of the gold, "these are the first studies to reveal a strong effect."

One ounce of gold wire, three-thousandths of an inch in diameter, was used in the test, which was sponsored by the Air Force's Office of Scientific Research through the U-M's Engineering Research Institute.

Because the gold had a "half-life" of three days—that is, it lost half its strength the first three days, half the remainder the next three, and so on—special arrangements had to be made for the experiment, Professor Churchill said.

An Air Force plane picked up the source shortly after it was removed from an Atomic Energy Commission nuclear reactor at Idaho Falls, Ida. Carried in a 1000-lb. lead container, the gold was flown to the University's Willow Run Airport, where the plane taxied to within a few hundred yards of where the experiment was to be run.

A truck carried the container to the laboratory, and the gold was unloaded and installed under water within 24 hours after leaving the reactor. Thirty tons of bagged cement and one and one-half tons of lead sheet were placed around the apparatus, and the water drained away.

A stream of propane gas was directed through the "nest" of radioactive wire, then ignited. Propane is a component of natural gas and gasoline, and Professor Churchill and his associates believe other fuels would behave the same way.

Because work had to proceed 24 hours a day for three weeks, and because each person could remain in the area only a short period of time so as to not exceed his radiation tolerance, about 20 engineers were marshalled for the project.

When they were finished, the gold had lost most of its potency. "That is one of the advantages of using such a source," Prof. Churchill said. "There is no waste problem when you are finished."

"Cat Eye" to View Mars.—The "Cat Eye" light amplifier of the U. S. Air Force's Air Research and Development Command (ARDC), may provide the means for answering the questions about the "canals" on the planet Mars. It may also provide the answers to other questions that have long concerned astronomers.

This may be accomplished by tak-

ing better photographs than previously possible, even with the finest telescopes, using conventional photographic methods.

The "Cat Eye" which grew out of a research program of the Air Research and Development Command under the sponsorship of ARDC's Aeronautical Research Laboratory at Wright Air Development Center WADC), Dayton, Ohio, can see a scene at night and reproduce it with daylight brightness, even when the human eye can see nothing. Research work on "Cat Eye" transducers was conducted for ARDC by Westinghouse Corporation and the Radio Corporation of America.

Conventional photographs of planets and other heavenly bodies taken even with the best telescopes suffer from the "jitters." The "jitter" is caused by tremors of air masses in the earth's atmosphere which affect the resolution of distant objects such as planets and galaxies, because the light is deflected first in one direction and then in another. An example is the shimmering of starlight seen on a clear night. This shimmer causes the photographs to blur, since conventional photographic techniques require exposures of several seconds for Mars, and even longer periods for more distant planets or the stars.

By using "Cat Eye" with a telescope of only 24-in. diameter, it is expected that pictures of Mars may be made in a few thousandths of a second thereby shooting "between" the tremors in the atmosphere.

To the human eye, light appears to be steady and continuous. Actually it is composed of many separate photons, each of which is a separate small train of light waves. The human eye detects only about one photon in twenty, enough to see by daylight or lamplight.

In comparison, the "Cat Eye" contains a transducer which collects and converts photons much more efficiently than the human eye. It permits a useful total light amplification of several hundred million times. Also, the latest transducer is especially improved in sensitivity in the red and near infrared portions of the spectrum, which are most suitable for observations of planets.

Photographic exposure times can be reduced 16,000 times with "Cat Eye," according to Mr. Radames K. H. Gebel, of WADC's Aeronautical Research Laboratory. This will permit photographs that might reveal the nature of the "canals" and other features of Mars, and also make it possible to see perhaps 100 times farther into space than with the finest telescopes using conventional photography. A transducer produced by RCA is especially suitable for this long distance photography.

Although the time and place for the first astronomical uses of the "Cat Eye" have not yet been chosen, Dr. Lee Devol, Chief of WADC's Engineering Physics Research Branch, said that the matter is being discussed with leading astronomers.

Brigadier General Thomas L. Bryan, Jr., Commander of WADC, said that technical development work on the new transducer has been initiated by the Center's Electronic Components Laboratory which will prepare them for use in aircraft. The Center's Aerial Reconnaissance Laboratory is planning integration of the "Cat Eye" into reconnaissance systems which can take aerial pictures at night.

Artificial Respiration by Electronics.— A new experimental electronic system that enables a polio victim to use respiratory muscles that are still intact to control the breathing of his iron lung was described at the In-

stitute of Radio Engineers' annual convention. The novel system was described by Dr. L. H. Montgomery, of the Vanderbilt University School of Medicine, who stated that although the equipment is still in an experimental stage, the National Foundation for Infantile Paralysis plans to make it available to polio centers "as soon as it is practical to do so."

Even in the severest cases of paralysis, Dr. Montgomery reported, the victim is left with control of a few muscles which contract when he tries to breath. This contraction generates minute voltages that can be detected by sensitive electrodes placed on the skin. The voltages are then fed to electronic equipment which amplifies them and uses them to control the flow of air to and from the iron lung or other type of respirator in accordance with the patient's needs.

The new respirator is expected to be a great boon to patient morale and comfort. In previous types he is compelled to eat, drink and talk in rhythm with a motor driven air pump, whereas, now he will be able to control his own breathing to suit himself.

Electronic Mail Sorting System Proposed.—An electronic system for sorting mail automatically was disclosed at the Institute of Radio Engineers national convention recently. The system, described by M. M. Levy and A. Barszezewski, is under development by the Canadian Post Office Department in Ottawa. Operators in special reading stations convert the names of towns, villages and streets into a special code suitable for electronic handling. After the code is marked on the envelope by a special keyboard, the remaining operations may be performed completely automatically by high-speed electronic sorting equipment.

Atomic Power Plant for *Seawolf*.—The atomic power plant for the Navy submarine *Seawolf*, recently commissioned, should be able to drive the *Seawolf* the equivalent of more than three times around the world, consuming an amount of fuel about the size of a softball.

Frederick E. Crever, general manager of the Knolls Atomic Power Laboratory (KAPL) said that the *Seawolf* power plant, developed and designed at KAPL, could operate for more than 80,000 miles without need for a new fuel charge.

The nuclear reactors used in both the prototype plant and the *Seawolf* are classified as intermediate energy neutron spectrum reactors. Mr. Crever said that their design and operation represent a major technological and engineering contribution to the nation's program of reactor development.

The selection of liquid metal coolant for use as a primary fluid in the power plant system was made to secure the advantages of high pressure, high temperature steam for use in small-size, modern steam turbines and propulsion equipment, he explained.

"As has been reported in the press during the past several months, fundamental corrosion and metallurgical problems have developed in certain components of the steam generating system in the *Seawolf* power plant as well as in these components in the prototype located at West Milton," Mr. Crever stated.

The success of the pressurized water cycle used in the submarine *Nautilus* and the adequacy of this cycle to satisfy all the presently known needs of a nuclear Navy have resulted in Navy actions to terminate further development of the sodium cycle for submarine application, the KAPL general manager said.

KAPL scientists and engineers are

now working on two new projects for the Navy, both utilizing pressurized water cycles. They are the Submarine Advance Reactor which will power the new Navy submarine *Triton*, now under construction at Groton Conn., by the Electric Boat Division of the General Dynamics Corporation, and the power plant for a Navy destroyer class vessel. The *Triton*, to be the largest underwater craft ever built, will be designed to operate in conjunction with a fast carrier task force and to provide it with radar information.

Mr. Crever said that "it is proposed that protoyotype power plants of both the Naval units will be erected and operated at KAPL's West Milton, N. Y., test site prior to the construction of the shipboard units."

It is further proposed, he said, that the steel sphere at the West Milton site be retained for possible future use in experimental operation of prototype nuclear power plants. Operation of the prototype of the *Seawolf*'s power unit was terminated March 1, 1957.

The *Seawolf* prototype plant went critical in March, 1955. In June that year, the unit completed a run which would have taken it the equivalent of 2,250 miles non-stop, fully submerged. This is the distance between St. Johns, Newfoundland, and Dover, England.

On July 18, 1955, excess steam from the prototype was used to produce the free world's first commercially distributed atomic power for homes and industries. It was on that day that steam generated in the prototype unit first turned a General Electric turbine-generator to produce atomic electricity to be sent over lines of the Niagara Mohawk Power Corporation.

The *Seawolf* was launched July 21, 1955, at Groton, Conn., by the Electric Boat Division of the General Dynamics Corporation, and has completed initial sea trials, operating both surface and submerged, responding fully to all maneuvers without incident, Crever said.

Year-Round Air Conditioning with Heat Pumps.—An ingenious heating-cooling method called a heat pump, which was originated more than 100 years ago, is today attracting major interest as a means of providing year-round air conditioning for commercial and industrial buildings.

According to William Hillen, applied equipment sales manager for Carrier Corporation, Syracuse, N. Y., there are solid economic reasons for this current rising acceptance. One of the important ones is the fact that many utilities are promoting the use of electrically-operated heating equipment in winter to balance the heavy demand for electricity in the summertime resulting from the growth of air conditioning. Another is the fascinating number of ways that heat pump systems can be engineered for particular jobs in order to provide maximum economy for the particular requirements of the customer.

The time is past when heat pumps —with few exceptions—were designed primarily for the mild climate of the Southeast and California coastal areas. Today in places much farther North a heat pump may be practical because there are so many newlydeveloped ways of putting a system together.

Carrier Corporation, which has been installing heat pump systems for years, recently introduced a new packaged heat pump for residential and small commercial buildings and also announced a new series of assemblies and detailed information for job-engineered heat pump systems.

The wide range of installation possibilities has given new life to the use of heat pumps in many sections of the country, Mr. Hillen said.

Essentially, a heat pump is a device which takes heat from one place and discharges it at a higher temperature in another. Thus in the summer a conventional air conditioning system is a heat pump because it takes heat from inside the room it is cooling and discharges it outside. And in the winter a heat pump system turns itself around and takes heat from outside the space and discharges it into the room to be warmed.

Almost anything might serve as a source of heat—even a block of ice has heat in it—but the most practical sources to date are water and air. And one of the most fascinating aspects of such a system is that you are actually taking heat from another substance rather than converting fuel or power into heat, and thus you are getting something for nothing. In a water-source heat pump, you might get as many as seven units of heat energy for every unit of electrical energy put into the system.

Wherever there is a cheap, dependable, easily disposed of supply of good water, a water-source heat pump is likely to be the choice. Where it isn't, air as a source is the probable answer, and it is here that the extraordinary array of different, job-engineered heat pump systems will be used.

The most common approach is simply to draw outside air over a coil where heat will be extracted from it by refrigerant evaporating inside. The heat may then be discharged into the conditioned space through forced air ducts or through warm water piping connected to air conditioning convectors in each room.

But in many applications, people, lights, office or industrial machinery, or even cows and pigs may serve as so many little furnaces to help heat other spaces.

Consider the farmer with a well-insulated cattle or pig barn. The animals in the barn may be producing more than enough heat to keep it warm in winter. With a heat pump, the farmer might take the heat while throwing away the odor, and use it to warm his house in winter.

A more likely place might be a department store where crowds and intense lighting create such large amounts of heat in shopping areas that cooling is required even in the dead of winter. In this application, cooling the air is actually a process of extracting heat from it and this can be sent to office spaces or other areas where heating is needed. Similar applications are possible in industrial plants when machinery or processes involving heat may create unpleasantly high temperature. A heat pump system can cool the plant and warm the offices at the same time.

Variations like these are making heat pump systems practical in much wider areas of the country, Mr. Hillen said.

He pointed out also that cold weather problems are frequently not so great as many people think

A survey taken by Carrier, he said, indicates that in a number of cities across the country considered "cold" there are actually comparatively few days during the year below freezing. Syracuse, N. Y., for example, in the middle of one of the nation's snow belts, enjoys temperatures above 30 degrees during 83 per cent of the year despite its hard, long, winters. Fort Wayne, Indiana, is above this level 84 per cent of the time; Raleigh, N. C., for 97 per cent; Kansas City, 91 per cent; Houston, 99 per cent and Miami, 100 per cent of the time.

One major advantage of the heat pump, the Carrier executive said, is the fact that a single system can provide year-round air conditioning. A heat pump provides warm, filtered

air in the winter, and cool, filtered, dehumidified air in the summer.

Air filtration, he pointed out, removes dust and dirt from the air. This in turn reduces routine upkeep, general refurbishing and redecorating to a minimum.

Confetti Solves Waterworks Problem.—Handfuls of confetti blown through an elaborate plastic model at The University of Michigan are helping civil engineers find how a planned $6 million pumping station can best handle a billion gallons of Detroit's drinking water every day. The 6-ft. long, 4-ft. high model represents an underground facility to be built in Detroit's Waterworks Park, on the main intake line from the Detroit River. The confetti is carried through the model on a fast stream of air which simulates the thousands of tons of water that will rush through the station every hour. By watching through the clear plastic walls of the model, U-M engineers can spot turbulent eddies in the flying confetti. Then they devise ways to eliminate them.

"If there was excessive turbulence in the water, the station's pumps would not operate at full efficiency, and they would require higher maintenance costs," points out Prof. Victor L. Streeter, who heads the project. "The pumps would handle less water than they are designed to, and they would vibrate, become noisy and wear out faster."

Already, he says the $20,000 model has made possible a savings of over $100,000 in capitalized pumping costs by showing ways to conserve the energy of the water while reducing its turbulence.

"Whenever you lose the water's energy, you have to make it up somewhere along the line by increased pumping," he notes. "So far, we have been able to cut energy losses in half by adding turning vanes, baffles and other design features."

The proposed station will have the job of boosting water 25 ft. from the main conduit from the Belle Isle intake station. From the new station, the water will flow "downhill" to Detroit's Northeast and Springwells filtering plants, about seven and eleven miles away, respectively.

Water will enter the station in a conduit 14 ft. across, then drop into a crescent-shaped concrete pit 16 ft. deep and 90 ft. long. From there the impellers of four powerful pumps will push the water on its way with considerably more energy.

This operation has been reproduced in the model, with air replacing the flow of water and plastic sleeves the size of stove-pipes representing the steel conduits.

One inch on the model—built by the Cadillac Plastic and Chemical Company of Detroit—equals 21 in. of the proposed station.

By measuring air pressure at dozens of points in the model, and by tossing confetti into it, the researchers can tell how effective each of their design changes has been.

Professor Streeter points out that the station is designed to provide Detroit with over one billion gallons of water a day by 1970, or nearly twice the present supply.

Crystalline Structure of Polyethylene.—New data on the influence of crystalline structure in the cross-linking of polyethylene were revealed at a meeting of the American Chemical Society by three General Electric Co. scientists.

Experiments with polyethylene have indicated that when that plastic is irradiated in the completely amorphous state, electron radiation is more than seven times as effective in pro-

ducing cross-links as when it is irradiated in a highly crystalline state, according to a paper prepared by Elliott J. Lawton, John S. Balwit, and Roger S. Powell of the GE Research Laboratory, Schenectady, N. Y.

Most studies of such cross-linking in the past, declared Lawton, who presented the paper, have not taken into consideration the effect of the physical state of the polyethylene during the irradiation process. The experiments described today indicate that there is a strong temperature dependence in the cross-linking of polyethylene, springing from the fact that as the temperature is increased, a larger and larger proportion of the material passes into the amorphous, or noncrystalline, state.

"The shape of the [experimental] curves," Lawton told the audience of several hundred chemists, "implies that the main change in cross-linking efficiency is due to crystallinity present during the irradiation, and that the formation of intermolecular cross-links between adjacent molecules is very much dependent on the crystallinity and the physical state of the polymer during the irradiation."

The experiments were conducted with normal low density polyethylene and also with high density Marlex-50 polyethylene. The variations in experimental results between the two types of material supported the view that the efficiency of cross-linking was influenced by the degree of crystallinity, since Marlex-50 is more highly crystalline than normal polyethylene.

Atomic Isolation Booth.—An atomic area once closed to any persons without protective clothing now can be entered safely by those dressed in ordinary street clothes, thanks to a plexiglass shelter developed by General Electric Company personnel at the Hanford atomic plant.

General Electric, which operates the plant for the Atomic Energy Commission, has installed a safety shelter inside a "canyon" building to enable entrance without special protective clothing in an area where radioactive materials are chemically separated.

The shelter is constructed of ¼-in. plexiglass and provides clean air, free of radioactive dusts and other contaminants, from outside the "canyon" building.

Inside the "canyon," a concrete, windowless building three times longer than a football field, plutonium is separated from irradiated uranium fuel elements. Contamination in the area demands protection either from the protective clothing or the new plexiglass shelter.

Fuze Test Facility.—A live bomb fuze is dangerous. Ordinarily, they are handled with the greatest of care and respect—like egg shells loaded with nitro-glycerin.

"Fuze Testers" of the Air Research and Development Command (ARDC) take an opposite approach. They drop, jolt, shock, and dunk fuzes. They put them through sand, dust, salt, spray, humidity and rain. But they do it in safety. It's all part of a new facility to test fuzes until they meet all the rigorous military standards. The Fuze Test Facility, most complete of its kind in the Air Force, recently began operations at ARDC's Air Force Armament Center, Eglin Air Force Base, Florida.

Special equipment puts new fuzes through a variety of extreme conditions, as rough, or more so than actual operating situations. For example, there is the "jumble machine." An unprotected fuze is placed in a box and rotated 3,600 times at a speed of 30 revolutions per minute. If the fuze is still sound, it is put through 7200 more revolutions to determine

what margin of safety can be expected.

An 80-ft. tower tests fuzes for safety and ruggedness during design and production phases. The fuze is placed in an insert bomb, projectile or warhead and dropped 40 to 80 ft. onto a steel plate. Five drops are made. Each time the fuze strikes the plate at a different angle. Sometimes the bombs weigh as much as 750 lb.

Explosives contained in the fuzes necessitate elaborate safety precautions. A gamma ray machine (sort of an X-ray device) determines the condition of the fuze after tests. The machine, which one person can move about, can "see" through as much as eight inches of steel.

The facility's Remote Control Laboratory is another safety precaution. Here, fuzes are examined, inerted and sectioned by remote control. A closed-loop television hook-up gives the operator a full view of what is taking place in the lab.

Among the instruments and machines to be added to the new facility within the next year will be a "retarding" tank, 58 ft. long and filled with soap bubbles. Projectiles fired into this tank will be slowed down from speeds of about 3200 ft. per second to 400 ft. per second, and then stopped by a catch box filled with a low-density material. Testers can then recover fuzes that have not been deformed.

The Fuze Test Facility is operated by the Fuze Test Branch of the Directorate of Munitions at ARDC's Armament Center. Diamond Ordnance Fuze Laboratories designed the facility in cooperation with the Center and other service agencies involved in fuze testing.

Wooden Ladder Turned Into "Toast."—The case of a wooden ladder which electron irradiation accidentally turned into something tasting like dry toast was described recently by a General Electric Company safety engineer.

The 6-ft. wooden ladder stood for about two years close to a high powered electron-beam generator used in experiments to determine the effect of radiation on various materials. Stray electrons scattering from the materials under study slowly irradiated the ladder, changing it into an edible substance much weaker than wood, according to Howard H. Fawcett, of the General Electric Research Laboratory in Schenectady, N. Y. The weakened ladder eventually broke.

"The chips of wood that I sampled," said Fawcett, "tasted a great deal like slightly sweetened dry toast, which crumbled easily into powder."

Fawcett described the incident before some 100 safety experts attending a meeting of the Laboratory Sub-Section of the National Safety Council.

The irradiation of the ladder, although completely unintentional, represented a phenomenon which GE Research Laboratory scientists first investigated several years ago. In these early experiments the scientists discovered that by bombarding wood with beams of electrons they could convert the cellulose in the wood into a substance which could be digested by the bacteria in a cow's stomach. The wood then possessed food value approximately equal to that of hay. The costs involved in this conversion, however, make it unlikely that the woodpile will ever replace the silo.

Studies of the effects of electron irradiation on various materials began in the GE Research Laboratory as early as 1926. These led to the announcement, in 1954, of the development of the first commercial product produced by means of electron irradiation: "Irrathene" irradiated polyethylene, used mainly for

electrical insulation. A broad program of study continues on the effects of irradiation on plastics, bacteria, foods, and drugs, but only incidentally on ladders.

Glass Shielding Brick.—A new type of glass shielding brick that is as dense as iron, and ⅔ as dense as lead, has been announced by The Atomic Center of New York City. Used as an insert in a metallic or concrete wall, the lead glass brick enables the worker to observe the action, perform remote manipulations, and even read instruments behind the wall shield.

Three sizes of brick are cast, including a large 8 in. × 8 in. × 4 in. square block for maximum viewing angle. The bricks are composed of a special lead glass mixture, and are mounted in a steel frame for protection and handling.

Lead glass is the latest addition to the family of radiation shield building materials, which includes lead, iron and steel. For specific counting applications, upright cylindrical shields and "interlocking doughnut" types are also available.

3-D Atoms Offered as Chemical Study Aid.—Atoms in three dimensions, a model set which enables the scientist to study the space relationships in various molecules, have been introduced by Chicago Apparatus Company, laboratory equipment supplier.

The set consists of plastic balls in various sizes and colors, representing different atoms, and long, short, and flexible pegs which serve as the links between atoms.

Molecular models are an important aid in studying organic chemicals, crystals, and other complicated structures, the company explained. Research scientists find that "seeing" molecules in 3-D is an aid in problem solving or demonstration, and chemistry instructors use sets frequently in class work.

The Chicago Apparatus set is built to exact dimensions for proper valences and valence angles. Permanent, brilliant colors which are impregnated in the plastic designate carbon, hydrogen, nitrogen, phosphorus, sulfur, chlorine, bromine, iodine, fluorine, oxygen, and silicon atoms. Holes are precisely drilled to permit joining of the spheres by means of the pegs.

Chicago Apparatus offers a student set consisting of 69 balls and 59 pegs, a lecture set of 170 balls and 155 pegs, and a crystal set of 150 balls and 225 pegs.

Computers to Analyze Oil Well Drilling.—The use of electronic brains to speed oil well drilling and thus accelerate the discovery of new petroleum reserves has been predicted by Bryant Trenary, a General Electric Company engineer, before a meeting of the American Institute of Electrical Engineers in Oklahoma.

General Electric, he said, as part of its long-range planning, is exploring the use of computers to analyze drilling conditions and automatically control drilling rigs so that they will bore for oil more quickly and economically.

"Recent outstanding successes with the operation of electric transmissions on diesel-electric drilling rigs . . ." has suggested the application of computers, Trenary said.

He outlined the effects that factors including the weight on the drilling bit, the speed with which the bit is turned, and mud pump pressure, have on drilling and said that this data would be fed to the electronic brain which would compare it with previously-stored optimum combinations, and then automatically make any necessary corrections through controls to an electric drilling transmission.

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